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Element Contamination in Port Everglades – Preparing for Ecological Impacts

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By:

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Abstract

Port dredging is of economic importance worldwide but its impacts to the marine environment through the remobilization of elemental contaminants are not well understood. A massive deepening and widening of Port Everglades, Florida, will begin in 2023. Contaminated sediment disturbed during the dredging process could be released and prove to be harmful to three coral reef tracks located beginning 1.5 miles away from the port. This study focused on identifying and quantifying 14 different trace elements: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), tin (Sn), vanadium (V), and zinc (Zn) in Port Everglades, West Lake, and the coral reef sites before dredging commences, using induced coupled plasma mass spectrometry. All 14 elements were found within 5 of 10 port cores, with five cores displaying non-detected (n/d) values of mercury (Hg). West Lake contained all 14 elements, 13 out of 14 elements were found in North Reef samples (n/d values of Hg), and all 14 elements were found in the South Reef samples. Arsenic (As) concentrations in all cores exceeded probable effect levels (PEL, 41.6 µg/g) and molybdenum (Mo) concentrations in all cores exceeded the background continental crust (1.5µg/g) by up to 256 %. Additional element concentration spikes above the threshold effect levels (TEL) included cadmium, chromium, copper, lead, mercury, nickel, and zinc. This study provides evidence of elemental contamination within Port Everglades and its potential harmful impact through remobilization to the threatened reef sites.

Key words: Elemental contamination, sediment, marine sediment cores, Port Everglades, coral reefs, SECLER

Introduction

Port Everglades History

Ports are vital to the U.S. economy as they serve to transport various goods such as cargo, fuel, and passengers all over the world. American Association of Port Authorities (AAPA) reports that 99 % of the country's overseas cargo by volume is handled by seaports (American Association of Port Authorities, 2013). Additionally, Seaport industries also provide jobs to over 23 million Americans (EPA, 2020). One of the most important economical sources to South Florida is Port Everglades. Located in south Fort Lauderdale, Port Everglades was originally envisioned as a solution for "Florida's shipping bottlenecks" and has grown into one of the East Coast's most valuable seaports. (McGoun, 2002).

Port Everglades was opened in 1928. It was previously a mangrove swamp that surrounded an area coined 'Lake Mabel'. Maritime shipping of freight ships increased over the past century from 30,000 in 1900 to nearly 90,000 in the year 2000, along with an increase in cruise ships as well in response to globalization (Corbett et al., 2010). The rapid increase of ship traffic over the past century has led to increase port developments. Additionally, there has been a high demand for berth expansion to accommodate larger vessels, due to large population growth during the last century (porteverglades.net, 2020, Walker et al., 2012).

The parcel before Port Everglades was primarily used as a mean for local farmers to ship produce. Ideas began forming in the late 1800s and early 1900s to transform the naturally formed Lake Mabel, also known as Bay Mabel Harbor, into a more efficient means to transport goods. A resolution was passed in 1911 by the Florida Board of Trade for a Deepwater Port Project, enabling farmers to transport their produce to the north and west of Florida (Port Everglades History, porteverglades.org). In 1893, Frank and Marshall Stranahan arrived in South Florida with hopes to operate a ferry service and trading post near what was known as the time as "New River". The Stranahans then formed Fort Lauderdale Harbor Company in 1913, which served as a hub for small boats. This operation was completed by excavating Lake Mabel, which was referred to as an ideal site for operations to increase trade operations with Cuba by a Florida East Coast railway survey (Port Everglades History, porteverglades.org).

In the 1920s, Joseph Wesley Young, founder and major developer of the City of Hollywood, played a huge role in the development of Lake Mabel. The Great Miami Hurricane in 1926 significantly slowed port development progress (Port Everglades History, porteverglades.org). Due to the impact of the storm along with the Florida real estate crash, Young was no longer able to provide support for the project. However, the following year financiers took on the project and the Broward County Port Authority was established by the Florida legislature in 1927 (Port Everglades History, porteverglades.org).

Progress continued in 1929 as the port project was completed, the first airport was opened, and Port Everglades received its first cargo (86-meter SS Vogtland) and first military ship (carrying personnel of the 2nd Battalion of the Fleet Marine Force) (Port Everglades History, porteverglades.org). As development continued, goods such as food, fertilizer, fruits, vegetables, and sugar were prioritized for transport, and the first port manager, Florida Chamber of Commerce's Warren T. Eller, was hired in 1932 (Port Everglades History, porteverglades.org).

By 1950 Port Everglades was the port of call for many cruise lines (Port Everglades History, porteverglades.org). Florida Power and Light became a partner in the 1960s and purchased various lighting units within the port. During this time, petroleum and petroleum storage tanks had become one of the main products being transported within this area. The Foreign Trade Zone No. 25 was opened in the late 1970s, and the port supported its first rail-mounted container gantry crane as well. The first port-owned crane was acquired in 1981. By the late 1980s, thirty berths were operational, and eight cruise terminals were opened (porteverglades.org). The 1990s brought opening of parking garages, facility improvements for cruise and cargo terminals, and a transfer of governance from the Port Authority to the government of Broward County. This led to the boom in container ship traffic that is now seen today. In 2010, Port Everglades was estimated to have $13.9 billion in economic value to the State of Florida (Martin Associates 2010). A simplified history of Port Everglades can be found in Table 1.

The boom of ship traffic in the US over the past century has led to an increase in the number of ports being dredged to allow for larger container and cruise ships. Dredging projects in the surface waters of Florida have been regulated since the early 1970s to offer protection to surface waters from degradation due to pollution and the loss of wetlands caused by these construction activities. This includes wetland ecosystem, water quality (stormwater), water quantity (flooding), wildlife, and pollution regulations. All dredging activities are overseen by the following departments and water management districts: Northwest Florida, Suwanee River, St. Johns River, Southwest Florida, and South Florida, as well as the Army Corps of Engineers (Florida DEP, 2018). Due to these many activities, sediments are often sinks of contaminants for different types of chemicals, such as hydrocarbons, dioxins, pesticides, fertilizers, nutrients, and trace elements (Lucchetti, et al., 2017). Contaminants disturbed during the dredging process can be released and likely bioaccumulated by surrounding biological organisms. Evidence of this has been displayed in the sentinel crab (Macrophthalmus spp.), common periwinkle (Littorina littorea), and Sydney Rock oysters (Saccostrea glomerata) (Davies and Uyi, 2009; Hedge et al., 2009; Saadati et al., 2020).

The South Florida Water Management District manages nine major canals within the area that eventually drain into estuarine areas such as the Intracoastal Waterway and other associated bays and swamps. This discharge then makes its way from the Intracoastal waterway and into the Atlantic Ocean. Water discharges from the major canals can carry bacteria, oil and grease, pesticides, viruses, and toxic trace elements. Water within the Port is classified as Class III, i.e., acceptable for recreation, fish, and wildlife (U.S. Army Corps of Engineers, 2015).

Dredging and Impacts

Dredging includes the excavation and disposal of bottom material, which can have detrimental impacts on the marine environment (U.S. Army Corps of Engineers, 1983; ABP Research, 1999). Along with harming these aquatic environments, dredging processes and disposal have the potential to change bathymetry, alter water velocities, cause sedimentary regime changes, and erode seagrass beds (Erftemeijer and Lewis, 2006). Specifically, dredging large volumes of sediment will decrease water transparency and increase volume of suspended matter. If the suspended sediment is high in organic matter the resuspension of sediment may lead to changes in water quality as well due to the release of contaminants (Filho et al., 2004). Other implications related to dredging include destruction of benthic communities, nutrient concentration changes, and a decrease in dissolved oxygen levels. Coral reefs and seagrass beds can be most affected, as they are very sensitive ecosystems (Erftemeijer and Lewis, 2006).

Although dredging, or anthropogenic resuspension, is considered a destructive disturbance, natural processes such as bioturbation (resuspension of sediments by living organisms) aids in maintaining ecological balance within sediments. Effects of dredging activity will only be detrimental if the turbidity generated is greater than what is normally occurring in

Table 1. Timeline of Port Everglades History (1911 – 2023).

Deepwater Port Project	1911
Excavation of Lake Mabel to build the Port	1913
Port Everglades opened	1920s
Port Everglades completed	1930s
Maintenance dredging projects	1935-1939
Boom in Cruise Ship Operations	1950s
FPL Partnership and increase in petroleum use	1960s
Harbor deepening project	1962
Increased operation of berths and cruise terminals	1980s
Boom in Container Ship Traffic	1990s
Port Everglades estimated $13.9 billion economic value to South Florida	2010
Navigation channel maintenance project	2013
Dredging Project	2023

the area (Stern and Sickle, 1978; Orpin et al., 2004). In this case, the dredging operation will be extremely harmful to the surrounding ecosystem as there is typically little to no wave action caused by natural forces (e.g., storms, winds, and river discharges). Increased suspended sediments generated by dredging is usually no more than commercial shipping operations, bottom fishing, or severe storms, but the degree of harm depends on quantity frequency and duration of dredging, along with depth and physical dimensions of dredging location, grain size composition, density, and degree of contamination of dredged material, and proximity/distance of sensitive, ecologically/economically important ecosystems such as coral reefs (Pennekamp et al., 1996).

Sediments as Sinks for Contaminants

Sediments are described as inorganic or organic particles of biological, chemical, or mineral origin, and the benthic environments within them are highly sensitive, delicate ecosystems. Additionally, the sediment water boundary has the steepest chemical gradient and is most susceptible to disruption (Tuit and Wait, 2020). Marine sediment consists of a variety of materials on the seafloor, originating from biological productivity, continental erosion, cosmic debris, hydrothermal vents and/or volcanism (Dunlea et al., 2018). Sediment particles can be deposited and transported within aquatic systems and involve the interconnection between solid, liquid, and biological phases. Bioavailability of contaminants in sediments such as trace elements can change with depth along with changing seasonally due to temperature changes and various inputs of nutrients (Environment Canada, 1994; US EPA, 1994, 1995; USGS, 2005; Tuit and Wait, 2020). Suspended sediment is a major concern as it can bind contaminants and nutrients. These materials, after released, may become available for biological uptake (Mudroch, 1983).

Sediments of water bodies located in or near industrial locations may be highly polluted with organic and inorganic contaminants, depending on the types of activities in the area (Mecozzi et al., 2011). Economic development, for example, can result in environmental crises such as element pollution (Gao and Chen, 2012). Once trace elements are introduced into the water column, these tend to become incorporated into the underlying sediments, making sediments good indicators of contamination levels (Norville, 2005). Presence of trace elements within sediment can increase transfer within the marine food chain (Saadati et al., 2020); therefore, biomagnification and bioaccumulation are potential outcomes of the contaminants entering and remaining in the marine environment and can result in an even higher exposure that is already present within the ecosystem (Gao and Chen 2012).

Trace Elements and Heavy Metals in Sediment

In this study, heavy metals will be referred to as elements, as not all the elements analyzed are metals. However, heavy metal is a commonly used term. Heavy metals are generally defined as naturally occurring metals with a relatively high specific density that may negatively affect the environment and biota (Jakimska et al., 2011; Jaishankar et al., 2014). Heavy metals can be either essential or nonessential to organisms. Essential metals have biochemical and physiological functions, while nonessential metals do not have a biological function in the body (Tchounwou et al., 2012). Essential metals can be harmful at higher levels, but nonessential heavy metals may be highly toxic even at low concentrations. Furthermore, toxic concentrations of heavy metals and trace elements may be just above natural background levels (Jaishankar et al., 2014). Metals of concern for public health include arsenic (considered a metalloid), cadmium, chromium, lead, and mercury due to their high toxicity. The distribution of heavy metals is widespread as they are commonly used in the industrial, agricultural, pharmaceutical, and technological fields (Tchounwou et al., 2012).

Heavy metals have both natural and anthropogenic sources. Most heavy metals are present in the Earth's crust and enter the environment through erosion, volcanic eruptions, and other natural processes. However, many heavy metals are now also introduced into the environment through anthropogenic activities such as the burning of fossil fuels, mining, and industrial processes (Nriagu, 1989; Visschedijk et al., 2004). These metals include mercury, zinc, nickel, lead, cadmium, arsenic, copper, and vanadium (Pacyna et al., 2007; Fowler, 2013). Mining and its associated activities, including smelting and shipping, are large contributors of heavy metals to the environment. A direct relationship was found between the element that is mined and exported and the metals found in the marine environment (Valdes and Castillo, 2014). However, many other contaminants are released in this process. For example, mercury is a byproduct of the smelting of copper, zinc, lead, nickel, and gold (Pirrone et al., 2010). Selenium (considered a non-metal and trace element) is an essential element that is naturally present, but it is also introduced into the environment through the burning of coal and fossil fuels.

Arsenic, one of the most common toxins, is introduced anthropogenically through use in herbicides, pesticides, wood preservatives, oil and coal burning, trash incineration, and industrial sources (Rosen and Liu, 2010). Soil, groundwater, and runoff surrounding mines are often heavily contaminated with metals (El Khalil et al., 2008). As a result, heavy metal concentrations are usually elevated in local marine environments and bioaccumulate through trophic webs (Volesky, 1990; Valdés and Castillo, 2014). Heavy metals and trace elements are by-products of multiple industrial processes, varying amounts can get into the environment through waste discharge, anti-fouling paint and heavy fuel from cargo and cruise ships (Robson and Neal, 1997).

Trace elements enter the marine environment through atmospheric and land based effluent sources (Gonzálaz-Marcías, et al., 2006). Metals that are considered most toxic to marine life, in order of decreasing toxicity, include mercury, cadmium, silver, nickel, selenium, lead, copper, arsenic and zinc (Davies, 1979). Sediments can be extremely useful indicators for monitoring these anthropogenic contaminants within aquatic environments (Ergin, et al., 1991; Balls, et al., 1997; Atgin, et al., 2000).

Contaminated sediments in aquatic ecosystems throughout the world have been linked with potential human and ecological risks (Rifkin, et al., 2004). The distribution of these contaminants in aquatic ecosystems depends on the chemical and physical characteristics of these substances, properties of abiotic components and the structure and composition of the biotic community (Jennett et al., 1980). Additionally, partitioning of elements in marine ecosystems is determined by their association with bed sediments, suspended particulates, and organic matter; bottom sediments tend to be one of the major sinks for pollutants as they have the largest capacity for chemical storage (Francis, et al., 1983).

Trace elements have high ecological significance as they can accumulate in both sediment and biota (Nowrouzi and Pourkhabbaz, 2014). Most elements bind to fine-grained sediment fractions (<63 µm), as there is a high surface area to grain size ratio and humus matter content (Horowitz and Elrick, 1987; Moore, et al., 1989). The elements within this category display higher bioavailability than sediment fractions larger than 2 mm to 63 µm (Everaat and Fischer, 1992). Organic matter content plays a crucial role in sediment ecosystems, as it provides food sources for heterotrophic benthic organisms living below the photic zone (Yang, et al., 2010) and allowing for bioavailability and distribution of contaminants due to its high sorption affinity to hydrophobic organic contaminants and metals (Li et al., 2009; Fränzle et al., 2007).

Benthic communities within marine sediments are extremely biodiverse. Bacteria, ciliates, fungi, foraminifera, protozoa, meiofauna (nematodes, copepods, turbellarians), and macrofauna (polychaetes, crustaceans, mollusks, echinoderms) thrive in these environments, and all play a role to maintain the ecosystem balance. Bacteria are major players in the breakdown of detritus and help to decompose POC (particulate organic carbon), protozoa and meiofauna feed on bacteria, detritus, fungi and microalgae, and the majority of macrofauna are deposit (obtain nutrition from organic matter within sediments) or suspension feeders (obtain nutrition from passing particles in overlying water) (Snelgrove, 1997).

Benthic marine sediment ecosystems are nutrient rich, as there is a high amount of dead particulate organic material and benthic algae sinking to the bottom from surface waters. Additionally, the benthos can impact water column processes, trophic transfer, global carbon, nitrogen and sulfur cycles, pollutant metabolism, burial and transport, and sediment stability and transport (Snelgrove et al., 1997). The sediments that create these ecosystems are also considered to be a suitable means of identifying sources of element pollution in aquatic ecosystems (Schintu and Degetto, 1999).

The high affinity for metals allows for trace elements concentrate within organic matter and finer grained sediments (Seidemann 1991; Lin and Chen 1998; Espericueta et al., 2006). Wangersky (1986) reported high concentrations of trace elements in organic rich sediments. Additionally, metal concentrations (Cu, Cr, Pb, and Zn) have been found to be positively correlate with organic matter content, as well as a display of positive correlations between trace element adsorption of sediments and organic matter content (Lin and Chen, 1998).

Although many metals and trace elements are biologically essential (copper, nickel, zinc), all are toxic to biological organisms above specific threshold concentrations (Norville, 2005). Threshold effect levels (TEL) and probable effect levels (PEL) can be used as valuable tools to assess Numerical Sediment Quality Assessment Guidelines (SQAG) (MacDonald and Ingersoll, 1993). The threshold effect levels indicate element concentrations in sediment in which benthic organisms have started to exhibit toxic responses, while the probable effect levels indicate concentrations in which a large percentage of benthic organisms have exhibited toxic responses (Geoenvironmental Engineering, 2015).

Background, or baseline, values consisting of surface averages of continental crust composition can also be used to assess sediment contamination. These values are derived from the upper continental crust (the most accessible part of Earth), which is frequently used for various geochemical investigations. The two used methods to determine composition of the upper crust include 1) establishing weighted averages of rocks exposed at the surface and 2) establishing composition averages of insoluble elements in fine-grained clastic sedimentary rocks or glacial rocks and using these values to extrapolate the composition of the upper crust (Clarke, 1889). Composition averages derived from three continents, including the post-Archean Australian average shale (PAAS), European shale composite (ES) and North American shale composite (NASC) samples (Taylor and McLennan, 1995). Chemical compositions of various elements derived from the samples can also be utilized to determine the severity of contamination within sediment samples.

Arsenic

Arsenic is the 20th most abundant element on earth and is released naturally due to weathering of arsenic-rich rocks and volcanic activity. Arsenic is released into the environment via anthropogenic sources as well, such as herbicides, pesticides, plant defoliants and preservatives. It is also commonly used in various pigments, alloys with lead and copper, glass making, and for medicinal purposes (MacDonald and Ingersoll, 1993).

Arsenic is prominently toxic and carcinogenic. In its inorganic forms, arsenic is lethal to the environment and organisms (Jaishankar et al., 2014). The toxicity of arsenic to marine organisms is particularly complicated due to the existence of two different inorganic arsenic species – As (III) and As (V); both can be found in aquatic ecosystems (Liber et al., 2011).

Various sublethal effects on behavior, growth, locomotion, reproduction and respiration have displayed results that arsenic is acutely toxic to marine organisms (MacDonald and Ingersoll, 1993). Four studies with freshwater invertebrates (Anderson, 1946; Borgmann et al., 1980; Spehar et al., 1980; Golding et al., 1997) determined that As (III) is generally more toxic than As (V). One of the major sinks for arsenic is in sediments (Pierce and Moore, 1982).

Marine sediments can contain substantial concentrations of total arsenic (100-300 µg/g). However, environmental conditions can influence these concentrations; for example, anaerobic incubation of flooded soils and sediments will increase arsenic concentrations in porewaters (Brannon, 1987). Arsenic concentrations in surface water typically occurs in a soluble form that will co-precipitate with hydrated aluminum and iron oxides or is adsorbed by organic matter within the sediments (MacDonald and Ingersoll, 1993). Arsenic will also co-precipitate or adsorb easily on other metal sulfides (Demayo et al., 1979). The upper continental crust value of arsenic is 1.5 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of arsenic to marine biota is represented by a TEL value of 7.2 µg/g and a PEL value of 41.6 µg/g (MacDonald and Ingersoll, 1993).

Cadmium

Cadmium is a by-product of zinc production and is often found in soil where it is absorbed and accumulated in plants (Irfan et al., 2013; Jaishankar et al., 2014). Cadmium has similar chemical properties to zinc and can replace zinc in metallothionein, acting as an inhibitor. It can also be found in biocides, batteries, pigments, telephone wires, and may be present in phosphate rocks used for fertilizers (MacDonald and Ingersoll, 1993). Anthropogenic sources of cadmium in the marine environment include mining, metal smelting, agricultural uses, fertilizers, pesticides, alloys, paints, and the burning of fossil fuels (CCREM, 1987).

Cadmium transport within sediments typically occurs through organic matter and through co-precipitation with aluminum, iron and manganese oxides (Jaagumagi, 1992). Biological availability of cadmium depends on factors such as pH, redox potential, and water hardness (MacDonald and Ingersoll, 1993).

Cadmium toxicity has been found to be potentially harmful for aquatic insect larvae in sediments. Midge larvae exposed to cadmium, as well as chromium and zinc contaminated sediments displayed lower survival rates, decreased length and weight and reduced frequencies of emergence (Wentsel et al., 1977b, 1978). Additionally, chironomid larvae were found to avoid sediments containing > 422 µg/g Cd and > 8330 µg/g Zn (Wentsel et al., 1977b, 1978), and cadmium levels as low as 6.9 µg/g is toxic to marine amphipods (Swartz et al., 1985).

Francis et al. (1983) confirmed the high sorption capacity of cadmium from small quantities of the trace elements mobilized from element-enriched sediments. Sediments containing 100 to 1000 µg/g Cd were discovered to have released ≤ 0.01 % of the metal into surface waters, demonstrating the potential of bottom sediments to behave as sinks for trace elements (Francis et al., 1983). The upper continental crust value of cadmium is 0.098 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of cadmium to marine biota is represented by a TEL value of 0.68 μg/g and a PEL value of 4.2 μg/g (MacDonald and Ingersoll, 1993).

Chromium

Chromium is the 7th most abundant element on Earth and is present in many oxidation states. It is used in various industrial processes, such as the production of chrome alloys and chromium metals, as well as uses in the chemical industry in the production of ceramics, dyes, explosives, paints, and paper (MacDonald and Ingersoll, 1993). Anthropogenic sources of chromium include the production of chromium steels, ferrochromium and metal plating industry emissions, coal and oil burning, and cement manufacturing (Taylor et al., 1979).

The most common forms of this trace metallic element are Cr (III) and Cr (VI); behavior in these two oxidation states differ greatly. Cr (VI) is the dominant form under oxic conditions and typically exists as hydrogen chromate ($HCrO_4^-$) or chromate (CrO_4^{-2}), depending on pH. There is clear evidence that exposure to certain levels of Cr (VI) can result in significant health risks in humans, as the soluble form of chromium can readily pass-through cell membranes and oxidize intracellular compounds (Rifkin et al., 2004).

Chromium was first used in the production of stainless steel and coatings (Chandra and Kulshreshtha, 2004). Additionally, chromium is widely used in dyes, pigments, wood processing, photography, textiles, and leather tanning. Due to its widespread industrial use, chromium has been introduced as a byproduct into marine and terrestrial ecosystems, e.g., water, soil, sediment, and air (Rifkin et al., 2004).

In the marine environment, aquatic plants play a crucial role in the uptake, storage, and recycling of metals, such as chromium (Chandra and Kulshreshtha, 2004). A study conducted by Berry et al. (2002) examined mortality rates in amphipods with Cr (III) and Cr (VI) in sediment at concentrations ranging from 10 to 100,000 μg/g Cr. Amphipods exposed to Cr (III) experienced approximately 10 % mortality rate at the most highly spiked sediment, however, amphipods exposed to Cr (VI) experienced significant mortality rates (> 90 %) at concentrations starting at 1000 μg/g Cr. The upper continental crust value of chromium is 35 μg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of chromium to marine biota is represented by a TEL value of 52.3 μg/g and a PEL value of 160 μg/g (MacDonald and Ingersoll, 1993).

Cobalt

Cobalt is a relatively rare metal. Recent measurements in seawater suggest that cobalt is scavenged from the deep sea and follows a biogeochemical pathway similar to manganese (Heggie and Lewis, 1984). Exposure to cobalt is mainly a concern for industrial workers, but the general public consumes trace amounts of cobalt through fish and vegetables (Barceloux and Barceloux, 1999). Mild effects of cobalt exposure include reversible hematological and endocrine symptoms, but exposure to high concentrations of cobalt can lead to neurologic and cardiac symptoms (Leyssens et al., 2017). The mechanism of cobalt toxicity is not fully understood, but it appears to damage calcium pumps (Simonsen et al., 2012).

Cobalt toxicity interferes with the homeostasis of calcium and iron which can lead to the disruption of many body functions (Leyssens et al., 2017). Heggie and Lewis (1984) discovered solid-phase concentrations of cobalt in surface sediments to be almost double the level of deep-sea concentrations, indicating large portions of sedimentary cobalt are recycled with manganese between porewaters and redistributed in surface sediments. The upper continental crust value of cobalt is 10 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of cobalt to marine biota represented by TEL and PEL has not been recorded in the literature.

Copper

Copper is a common metallic element that exists in three forms: Cu, Cu (I), and Cu (II) and is biologically available since it is essential for the proper growth of animals (Flemming and Trevors, 1989; Ikemoto et al., 2004). Weathering or the solution of copper-bearing metals, copper sulfides and native copper are natural sources of this element within marine ecosystems (MacDonald and Ingersoll, 1993). Anthropogenic sources of copper include copper wire mills, coal burning industries, smelting, and refining industries, and iron and steel producing industries (CCREM, 1987). Copper is an essential micronutrient (MacDonald and Ingersoll, 1993); therefore, it is easily and readily accumulated by marine organisms, especially plants. However, copper can be toxic to bivalve mollusks, altering the biochemical and physical properties of the surface epithelium and disrupting membrane permeability (Cheng, 1979). Dean et al. (2007) discovered that a significant amount of copper in marine sediments in fish farms originated from anti-fouling agents. These can be released in either solid or particulate form, from either trapped nets or chipped off hard structures (i.e., container ships) into the marine environment (Claisse and Alzieu, 1993; Miller, 1994; Brooks, 2000; Morrisey et al., 2000; Solberg et al., 2002; Brooks and Mahnken, 2003). The upper continental crust value of copper is 25 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of copper to marine biota is represented by a TEL value of 18.7 µg/g and a PEL value of 108 µg/g (MacDonald and Ingersoll, 1993).

Lead

Lead is a highly toxic, nonessential metal that is absorbed by plants where it causes damage to chlorophyll and photosynthetic processes and suppresses the overall growth (Jaishankar et al., 2014; Najeeb et al., 2014). The main uses of lead include the manufacturing of lead-zinc batteries, and gasoline alkyl lead additives. Construction materials, electroplating, coatings, dyes, glassware, paints, and storage tank linings, transport of radioactive materials, and roofing are other various uses of lead (CCREM, 1987; MacDonald and Ingersoll, 1993). Lead in the marine environment tends to stay tightly bound to marine sediments under oxidizing conditions and is mainly distributed by atmospheric and riverine inputs (Ottley and Harrison, 1991; Turner et al., 1991; MacDonald and Ingersoll, 1993; Grousset et al., 1999) where it is released by high temperature processes and combustion of leaded fuel due to its volatile nature. Lead has the potential to be toxic to marine life due to concentrations in surface sediments in coastal areas (Stamatis et al., 2006).

Heinz et al. (1999) found one in ten mallards (Anas platyrhynchos) died due to 24 % lead-contaminated sediment (3400 µg/g) and that protoporphyrin levels in the blood were positively correlated with lead concentrations as well. Therefore, lead in sediment can pose a significant threat to waterfowl, which are known to consume large amounts of sediment while feeding (Heinz et al., 1999). Lead contamination in sediment in this area of study originated from spent shotgun pellets, lead fishing weights, and years of upstream mining activities. Anthropogenic values of total Pb concentrations were examined in surface sediments in the Gulf of Kavala, Greece and they ranged from 4 to 135 µg/g, with the total values (ranging from 25 to 209 µg/g Pb), indicating a high correlation to anthropogenic values. Deeper sampling sites displayed increased anthropogenic recovery (Stamatis et al., 2006). Gastropods exhibit toxic responses to lead as well. The upper continental crust value of lead is 20 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of lead to marine biota is represented by a TEL value of 30.2 µg/g and a PEL value of 112 µg/g (MacDonald and Ingersoll, 1993).

Manganese

Manganese is the 5th most common metal in the Earth's crust. Manganese pollution is common due to its ubiquitous natural occurrence, widespread associations with industrial processes, and high mobilization properties (Paschke et al., 2005; Li et al., 2013). Although Mn occurs naturally in sediments and soils due to the weathering of parent material, anthropogenic processes such as mining, smelting and addition of biosolids/organic wastes to agricultural areas have increased Mn concentrations in many areas (Paschke et al., 2005; Boudissa et al., 2006; Li et al., 2013). Li et al. (2013) studied anthropogenic Mn pollution of Yellow River sediment in the region of Ningxia, northwest China, an agricultural area with hundreds of irrigation channels. Various industrial plants have been established over time in this area due to large economic growth; however, they have contributed to a large portion of air, water, and sediment pollution. Mn values in Yellow River sediment included 750 µg/g at 0-5 cm depth, 673.4 µg/g at 45-50 cm depth and 620 µg/g at 95-100 cm depth (Li et al., 2013). The upper continental crust value of manganese is 600 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of manganese to marine biota represented by TEL and PEL has not been recorded in the literature.

Mercury

Mercury is the most well-studied trace element due to its extreme toxicity and high concentrations in the environment (Jaishankar et al., 2014). Mercury exists in three forms that vary in bioavailability and toxicity: the metallic element, inorganic salts, and organomercury compounds. These forms of mercury are taken up by microorganisms and methylated to produce the bioaccumulating methylmercury (Das et al., 2003; Jaishankar et al., 2014).

Methylmercury is an organic form of mercury that is lipid soluble and highly toxic (Das et al., 2003). The main form of mercury in sediment is mercury sulfide, which is highly insoluble (Tomiyasu et al., 2000). However, microorganisms in bottom mud can convert several mercury compounds into methylmercury (Johnels and Westermark, 1969). This element is commonly used for medicinal compounds, electrical equipment, the paint industry, paper industry, and in the production of chlorine. In the past, mercury-based pesticides were frequently used, however such practices have been banned (CCREM, 1987).

Marine sediment is considered a sink for mercury released into the environment due to the much longer lifetime of mercury in sediment. Additionally, mercury in sediment provides multiple depositional records (spatial distribution) and may provide temporal behavior of sedimentary mercury as well. Discharged mercury is sediment and its environmental impact has become a global concern (Nriagu et al., 1992; Akagi et al., 1995; Ikingura and Akagi, 1996). The main source of this contamination is the recent increase of mercury in gold mining in many developing countries (Tomiyasu et al., 2000).

Methylmercury is readily taken up by marine organisms. Therefore, sedimentary methylmercury may be re-taken up in the biogeochemical cycle and is likely to be bioaccumulated at high levels in marine organisms (CCREM, 1987). The upper continental crust value of mercury is 0.096 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of mercury to marine biota is represented by a TEL value of 0.13 µg/g and a PEL value of 0.70 µg/g (MacDonald and Ingersoll, 1993).

Molybdenum

Molybdenum is an essential element with low toxicity (Barceloux and Barceloux, 1999). It does not occur naturally in a pure metallic state, thus occurs in association with other elements. It is generally found as Mo (IV) and Mo (VI) in nature; Mo (IV) is often found as MoS_2 in mineral deposits (Fox and Doner, 2003). Many of the anthropogenic sources for molybdenum include mining operations (and by-products of copper-mining operations), municipal sewage, or coal combustion. Most molybdenum is used in stainless steel and cast-iron alloys (Barceloux and Barceloux, 1999). Invertebrate mortality in short-term tests have been reported at molybdenum concentrations greater than 28 µg/g, with some LC50 (lethal concentration) doses as high as 2650-3619 µg/g (Martin and Holdich, 1986; Khangarot, 1991; Naddy et al., 1995). The upper continental crust value of molybdenum is 1.5 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of molybdenum to marine biota represented by TEL and PEL has not been recorded in the literature.

Nickel

Nickel is the 23rd most abundant metal in the Earth's crust and typically occurs naturally in a combination with arsenic, antimony, and sulfur, and is commonly used in the production of nickel alloys, nickel plating and stainless steel (MacDonald and Ingersoll, 1993). Anthropogenic sources include electroplating industries, nickel ore mining, fossil fuel combustion, and smelting and mining activities (CCREM, 1987).

Nickel typically occurs in the Ni (II) form in aquatic ecosystems. In sediments, it is deposited due to the sorption to organic matter and co-precipitation with iron and manganese oxides (MacDonald and Ingersoll, 1993). Nickel within sediment also tends to form complexes with iron and manganese oxides (Jaagumagi, 1992).

The toxicity of dissolved nickel to marine invertebrates has been widely reported, with LC50 doses of 0.2 - 70 µg/g (Warnick and Bell, 1969; Biesinger and Christensen, 1972; Baudouin and Scoppa, 1974; Martin and Holdich, 1986; Khangarot and Ray, 1989, Schubauer-Berigan et al., 1993; Phipps et al., 1995; Doig and Liber, 2006). Further effects of nickel-contaminated sediments on aquatic organisms include reduction in growth, avoidance reactions, and mortality. In the presence of copper, the toxicity of nickel increases; therefore, the existence of both elements in sediment may be a factor that increases the contamination factor of Ni. The upper continental crust value of nickel is 20 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of nickel to marine biota is represented by a TEL value of 15.9 µg/g and a PEL value of 42.8 µg/g (MacDonald and Ingersoll, 1993).

Selenium

Selenium has mainly been studied for its role in selenoproteins and detoxification of heavy metals. The chemical forms of selenium in sediment are unknown, however, selenium may enter aquatic systems as selenite, selenate, or elemental selenium from smelting operations (Peters et al., 1999). Previous studies from Fowler and Benayoun (1976a), Lui et al. (1987), and Zhang et al. (1990) demonstrated evidence of food web bioaccumulation as the major route of selenium accrual in marine animals. However, selenium concentrations in organic detritus in sediments is thought to be a greater contributor to food web contamination than that dissolved in water (Canton and Van Derveer, 1997). Selenium values in selenium spiked sediment in Lake Macquarie, Australia (conducted by Peters et al., 1999) displayed evidence that two invertebrate species, polychaete Marphysa sanguinea and bivalve Spisula trigonella, amassed selenium from the spiked sediment, confirming bioaccumulation. The upper continental crust value of selenium is 50 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of selenium to marine biota represented by TEL and PEL has not been recorded in the literature.

Tin

Tin can be found as inorganic or organic forms in the environment (natural or anthropogenic sources) and occur naturally as inorganic forms within the Earth’s crust. Chronic exposure to tin can lead to accumulation in the kidneys, liver, and bones. The organometallic form of tin, organotin, primarily originates from anthropogenic sources. Short chain alkyl forms of tin, specifically butylin compounds, have a significant effect on gastropods as they simulate the development of male sex characteristics in female gastropods (Ostrakhovitch, 2015). Wong et al. (1982) discovered that organic tin compounds in green and blue algae cultures acted as inhibitors to primary production and reproduction.

Tributyltin (TBT), a member of the organotin compound family, is used in biocidal wood preservatives and the production of plastics. The most important tributyltin compounds include tributyltin fluoride (TBTF) and tributyltin oxide (TBTO) (MacDonald and Ingersoll, 1993). Tributyltin oxide is utilized as a slimicide in cooling water towers, a wood preservative, and marine anti-fouling paint for use on vessels of all types (MacDonald and Ingersoll, 1993; De Mora et al., 1995).

Tributyltin is frequently leached from the paint and is released into the water column and underlying sediments. TBT compounds are extremely toxic to marine life (flora and fauna). It was discovered that tributyltins can produce negative biological effects, even at extremely low levels. De Mora et al. (1995) examined surface sediments from the Auckland region of New Zealand following newly regulated introduction of organotin (TBT)-containing marine paint. Concentrations from 13 locations ranged from < 2 to 1360 µg/g. The high toxicity of TBT compounds and the elevated potential of their release into marine ecosystems makes them a significant threat in marine sediments (MacDonald and Ingersoll, 1993). Insufficient data exist to determine TEL and PEL toxicity levels for TBT compounds; however, Clark et al. (1987) observed 100 % mortality in grass shrimp exposed to tributyltin concentrations as low as 10 mg/g. The upper continental crust value of tin is 5.5 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of tin to marine biota represented by TEL and PEL has not been recorded in the literature.

Vanadium

Vanadium is a trace element, widely distributed throughout nature, and present in nearly all living organisms. It may exist in valence states ranging from +2 to +5. V (IV) and V (V) are dominant under moderately reducing and aerobic conditions (Fox and Doner, 2003). Major anthropogenic sources of vanadium include power-producing plants using fossil fuels, burning of coal wastes, and dumps of coal dusts in mining areas. Marine invertebrates, such as tunicates, have been found to accumulate vanadium levels up to 0.3 % dry weight. Aquatic plant growth can be simulated by trace amounts of vanadium, however above 100 µg/g are toxic (Venkataraman and Sudha, 2005). A sediment incubation study conducted by Amrhein et al. (1993) discovered that vanadium concentrations slowly decreased under reducing conditions, while under oxidizing conditions vanadium concentrations dropped to nearly zero. Additionally, values recorded by Fox and Doner (2003) indicated that vanadium generally decreased with increasing depth of soil cores. The upper continental crust value of vanadium is 60 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003). The toxicity of vanadium to marine biota represented by TEL and PEL has not been recorded in the literature.

Zinc

Zinc is the 24th most abundant element in the Earth's crust, and is used in alloys for die casting, dry batteries, brass, roofing, and in coatings to protect iron and steel (MacDonald and Ingersoll, 1993). Common sources of zinc in the marine environment originate from aerial deposition and riverine inputs (Neff, 2002). Major anthropogenic sources of zinc into the marine environment include atmospheric emissions, iron and steel production, wood combustion, municipal wastewater effluents, smelting, refining activities, and zinc mining (CCREM, 1987).

Zinc toxicity in sediments depends not only on its total concentration, but on mobility and reactivity to ecosystem components; adsorbed metals onto solid particles (i.e., sediment) are potentially available as they may be dissolved due to changes in salinity, pH, redox conditions, etc. (Rousseau et al., 2009). Zinc existing at a neutral pH can be deposited in sediments by sorption to clay minerals, organic matter, and hydrous iron and manganese oxides. However, sorption of organic matter seems to be the most significant environmental process in fine-grained sediments (Jaagumagi, 1992; MacDonald and Ingersoll, 1993). The upper continental crust value of zinc is 71 µg/g (Taylor et al. 1995; Rudnick and Gao, 2003), and the toxicity of zinc to marine biota is represented by a TEL value of 124 µg/g and a PEL value of 271 µg/g (MacDonald and Ingersoll, 1993).

Potential Impacts

Element contamination, which is frequently detected in sediments, has become a concern worldwide. Trace elements can stay in the sediment for long periods of time, but not forever. Combinations of chemical and physical water conditions will result in these contaminants to become available to overlying water and marine organisms. These contaminants can be significantly harmful to aquatic organisms, as well as having the potential to be toxic to humans through the food chain (Peng et al., 2009).

Port Everglades, located in direct proximity to the Intracoastal Waterway, exhibits characteristics of an estuarine environment, as it is semi-enclosed and connects to the ocean. Estuarine waters, the most productive marine ecosystems in the world (Underwood and Kromkamp, 1999) can receive significant anthropogenic input from point and non-point sources located within or near the estuary (Chapman and Wang, 2000). Historic contamination, such as decades' worth of port contaminants, remains a significant concern for these sediments and can have correlated effects on benthic and water column species (Hedgpeth, 1967; Varanasi et al. 1985; Nichols et al. 1986; French, 1993; Valette-Silver, 1993; Stein et al., 1995; Virkanen, 1998).

From 2013 to 2015, a dredging project in the Port of Miami, similar to the proposed Port Everglades dredging project, yielded significant sediment accumulation, resulting in a higher prevalence of partial mortality of corals (Miller et al., 2016). Although the dredging project will convenience many industries, it has the potential to be extremely harmful to the aquatic environment, particularly for benthic communities and corals, which take thousands of years to form.

Although the projected negative impacts are known, the consequences of dredging and other coastal construction are unavoidable due to the proximity of the reef ecosystems. Dredging reduces visibility and smothers reef organisms, leading to sediment rejection behaviors. Corals can display sediment rejection in various ways such as: corals polyp rejection, mucus production, ciliary/tentacular action, morphological variation (Erftemeijer et al., 2012). Southeast Florida's reef ecosystems are highly biodiverse, with several species of scleractinian and gorgonian corals, sponges, algae, and reef fish (Walker et al., 2012). Specifically, 27 species of scleractinian corals and 39 species of gorgonians can be found along Palm Beach, Broward, and Miami-Dade counties (Goldberg, 1973).

Study Importance

This study provides a first ever comprehensive approach to quantify element contamination within Port Everglades sediment and compare them with West Lake and the nearby coral reef sites. The temporal and spatial aspects of the sediment core samples are valuable first steps to understanding the accumulation of these elements and their variation within each core, site, and throughout Port Everglades. This research lays groundwork for future anthropogenic contamination research and environmental toxicology studies.

Objectives

The port sediment analysis focused on identifying and quantifying fourteen different trace elements in Port Everglades and the coral reef sediment prior to the 2023 proposed dredging project using induced coupled plasma mass spectrometry (ICP-MS). Fourteen trace elements (arsenic, cadmium, cobalt, chromium, copper, lead, mercury, manganese, molybdenum, nickel, selenium, tin, vanadium, and zinc) were measured in fourteen sediment cores 1-2m in length collected in Port Everglades and surrounding areas. These data have established contaminated element accumulation levels that could be released to the nearby coral reef track by the resuspension of sediment during the massive dredging operation.

Materials and Methods

Sample Collection

Permits for sediment core collection were provided by Broward County (Permit #ES2019-11), US Army Corps of Engineers (Permit #SAJ-2019-01644(NW-LCK)), and Florida DEP (Permit #05131935, Project #06-375933-001-EE). Sediment cores, collected on July 9-11, 2019, ranging from 1-2 meters in length, were collected from seven different locations via vibratory coring from a boat platform within and outside Port Everglades, Florida including 1) Dania Cutoff Canal (DCC): contained exposed mangroves and is located adjacent to the park road (26.064° N, 80.114° W), 2) Park Education Center (PEC): located within a semi-exposed mangrove channel with shallow tidal flow (26.084° N, 80.112° W), 3) Park Headquarters (PHQ): an exposed beach located south of Oceanographic Center along a small beach and lies within the Von D. Mizell – Eula Johnson State Park (26.07372º N, 80.11276º W), 4) South Turning Basin (STB): a semi-isolated canal surrounded by mangroves located within Port Everglades (26.075° N, 80.1162° W), 5) West Lake (WL): an isolated water body west of the intracoastal waterway, surrounded entirely by mangroves (26.075° N, 80.112° W), 6) North Reef (RF): Located between the first reef tract and Fort Lauderdale Beach, (26.110° N, 80.100° W), and 7) South Reef (RF): located between mooring balls and Park Beach, situated directly east of port gantry (26.074° N, 80.096° W). A map of coring locations can be found in Figure 1.

A Bradford pneumatic vibrator, powered by an air compressor, was clamped to aluminum barrels (measuring 7.5 cm diameter and 3 m length). This setup was further supported by a vibracore extraction land-based tripod. The United States Geological Survey (USGS) at the Davie and St. Petersburg locations provided the materials for and assisted in this process. Core catchers were positioned at the base of each barrel to ensure complete recovery of the sediments. The mechanical vibration of the pneumatic vibrator pushed the barrels into the sediment. Upon recovery of the sediment core, the barrel was removed from the water and the Bradford pneumatic vibrator was detached. The barrels were then cut to core length via pipe cutter and capped immediately. The core lengths were then measured, recorded, and prepared for transport.

The cores were split longitudinally at the USGS St. Petersburg Coastal and Marine Science Center using a custom-made sediment core splitter. Following the splitting process, each core segment was placed inside plastic sleeves prevent desiccation and prepared for transport to the USGS laboratory at the USGS laboratory at NSU's Center for Collaborative Research building, where they were stored horizontally at 4° C in a Continental CH3R-GD refrigerator. High resolution, panoramic photos were taken of each core prior to sampling to assess lamination following the sampling process. Subsamples of sediment (1 cm^3, 2-3 g) were taken at 5 cm intervals along the entire length of the core from surface to base. A total of 302 sediment samples were collected and analyzed for the 14 element concentrations.

Digestion and Analysis

Each sediment sample was washed three times with ultrapure deionized water (18.2 megohm) from a Barnstead water purification system. The sediments were then pre-dried overnight in an VWR drying oven for 18 hours at 80° C and then for five hours in a Fischer Scientific isotemp vacuum oven model 282A at 80° C at a pressure below 10^{-2} torr, using a 14008-01 model Welch 1400 DuoSeal vacuum pump. The dry weight of each sample was then recorded. The digestion technique used for this experiment was EPA Method 3050B (EPA). Ultrapure deionized water was added to reach the remaining volume of 100 mL.

Analyses were performed using a sector-field induced coupled plasma mass spectrometer (ICP-MS) (ThermoFisher Element XR) with a Peltier-cooler spray chamber (PC-3; Elemental Scientific, Inc.) at The University of Southern Mississippi's Center for Trace Analysis.

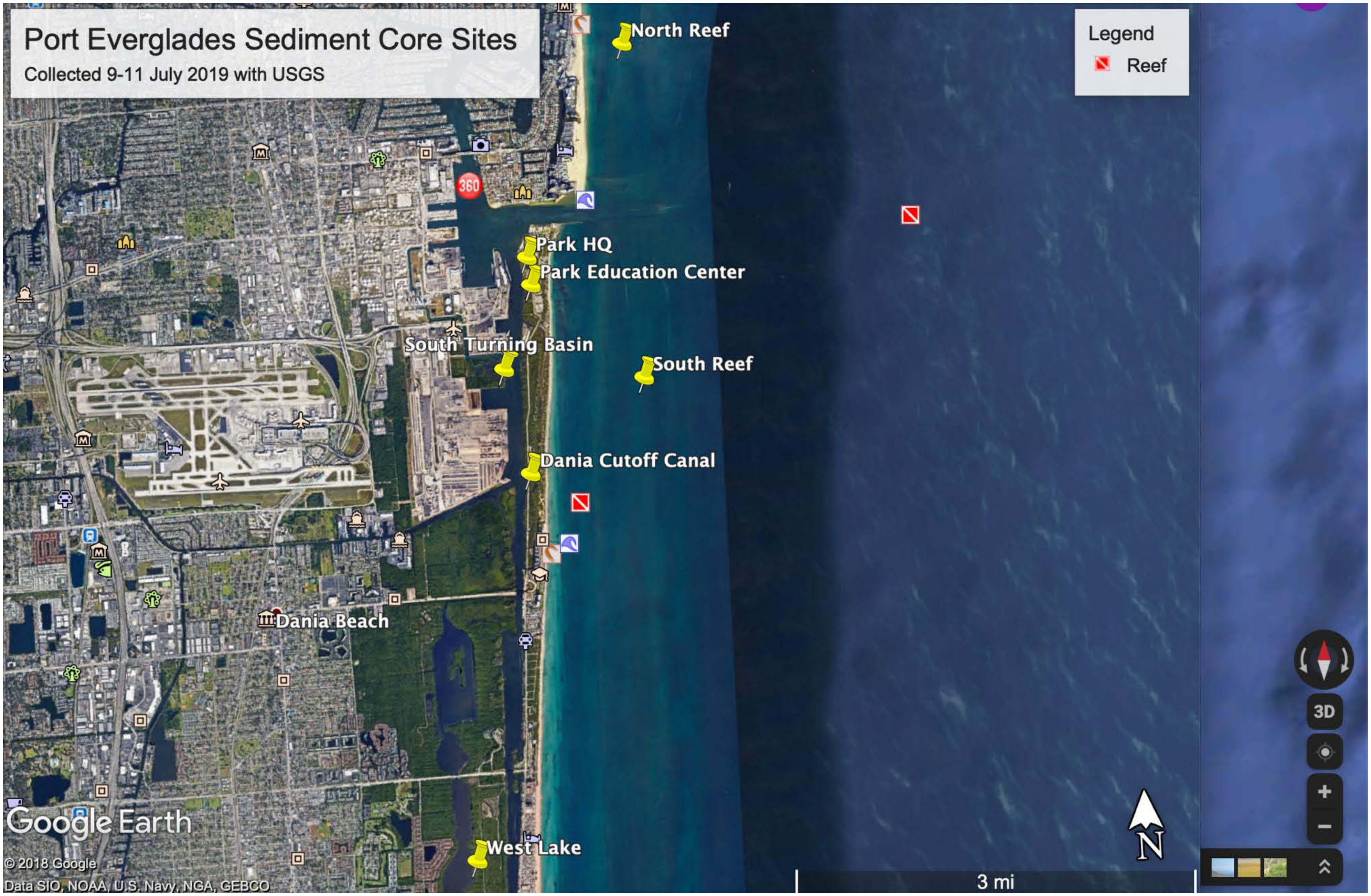

Figure 1. Map of Port Everglades showing Port Everglades, West Lake, and north and south reef sampling location

Concentrations of fourteen elements were measured for arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), molybdenum (Mo) manganese (Mn), mercury (Hg),nickel (Ni), selenium (Se), tin (Sn), vanadium (V), and zinc (Zn). Prior to analysis, digested samples were diluted 5-fold in 0.64 M ultrapure nitric acid (Seastar Baseline) containing 2 ppb indium as an internal standard. Diluted samples were held in acid-washed Teflon autosampler vials. Mass spectrometer scans were performed in low (Cd-111, Hg-199, 200, 201, 202, Pb-208), medium (Al-27, V-51, Cr-52, Mn-55, Fe-56, Co-59, Ni-60, Cu-63, Zn-66), and high (As-75, Se-77, 82) resolution, depending on the isotope. Mo-98 was monitored to correct for MoO^+ interference on Cd. Standardization was employed by external standards, with a high standard and a blank re-run every eight samples. For the elements (Hg, Se) where multiple isotopes were determined, no significant analytical differences were noted between the isotopes. Two USGS reference water concentrations were also assessed as part of each analytical run to verify the standardization. In several cases, sample calibration was also verified by standard additions. Blanks of ultrapure deionized water, hydrogen peroxide, and trace metal basis nitric acid (10 %) were used for quality control purposes. Detection limits were calculated as three times the standard deviation of the blank (Appendix Table 1). SRM (Standard Reference Material) was digested and analyzed as well to evaluate reliability of the analytical methods used in this study. The SRM recovery rates for As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Se, Sn, V, and Zn were 73 %, 89 %, 71 %, 62 %, 76 %, 66 %, 82 %, 48 %, 57 %, 79 %, 76 %, 31 %, 66 %, 77 %, respectively.

Continental Crust Composition

Continental crust chemical composition averages were derived from three continents, including the post-Archean Australian average shale (PAAS), European shale composite (ES) and North American shale composite (NASC) samples (Taylor and McLennan, 1995). These naturally occurring crustal compositions can be utilized to determine the severity of contamination within sediment samples.

Geo-accumulation Index

The geo-accumulation index (I_{geo}) measures the pollution intensity of individual sampling locations. This is a quantitative measure of the degree in contamination in sediments (Förstner et al., 1990). The I_{geo} is calculated with the following calculation:

$$I_{geo} = \log 2(\frac{Cn}{1.5xBn})$$

Cn represents measured concentrations within the sediment cores and Bn represents background levels of the continental crust (Rudnick and Gao, 2003). Mueller (1979) has provided values that quantify the degree of contamination from the above equation:

4 - 5: strongly to extremely contaminated

3 - 4: strongly contaminated

2 - 3: moderately to strongly contaminated

1 - 2: moderately contaminated

0 - 1: uncontaminated to moderately contaminated

< 0: uncontaminated.

Pollution Load Index

The pollution load index (PLI) has been proposed by Tomlinson et al. 1980. PLI is calculated using contamination factor (CF), represented by $C_{metal}/C_{background}$. The calculation for PLI is as follows:

$$PLI = (CF1 \text{ x } CF2 \text{ x } CF3 \text{ x} \ldots CFn)^{1/n}$$

where n = number of elements. This approach looks at elements within each sediment core as a whole and providing a PLI value that explains overall element pollution within each sediment sample. A sample with a PLI > 1 is classified as polluted while a sample with a PLI < 1 indicates that there is no contamination present (Tomlinson et al., 1980; Ray et al., 2006; Badr et al., 2009).

Potential Ecological Risk Index

The potential ecological risk index (PER) is another approach to observe the contamination degree of the overall element concentrations within each sediment sample (Jahan and Strezov, 2018). Guo et al. (2010) presented the following equation to determine the potential ecological risk index:

$$PER = \sum E$$

$$E = TC$$

$$T = Ca/Cb$$

where C_a = element content within sample and C_b = reference value of the element. T represents the toxic response factor as follows: Zn, Mn = 1, Cr = 2, Cu, Pb = 5, Ni = 6, As = 10, and Cd = 30 (Hakanson, 1980; Fu et al., 2009; Guo et al., 2010; Chen et al., 2014; Cao et al., 2015).

Threshold effect levels (TEL) and Probable effect levels (PEL)

Threshold effect levels (TEL) and probable effect levels (PEL) can be used as valuable tools to assess Numerical Sediment Quality Assessment Guidelines (SQAG) (MacDonald and Ingersoll, 1993). The threshold effect levels indicate element concentrations in sediment in which benthic organisms have started to exhibit toxic responses, while the probable effect levels indicate concentrations in which a large percentage of benthic organisms have exhibited toxic responses (Geoenvironmental Engineering, 2015).

Statistical Analysis

Statistical analyses were conducted with Microsoft Excel (v. 2012; Microsoft Corporation) and the statistical software PRIMER (v7, PRIMER-E Ltd). A parametric design was employed to assess differences among trace element concentrations at the seven sites and at every 5 cm. Single-factor one-way analysis of variance (ANOVA) was utilized to determine significant differences ($p < 0.05$) between and among elements within and across sample sites. The statistical software PRIMER (v7) was used to generate Pearson correlations to test for differences among the trace element concentrations. The Pearson correlation values were then used to create dendrograms and non-metric multi-dimensional scaling (MDS) cluster analyses to further investigate relationships between the element concentrations within the sediment cores. A single factor one-way ANOVA was performed to examine significant mean differences ($p < 0.05$) between maximum concentrations amongst coring locations and match paired t-tests were performed to further investigate the origin of the significant differences (v. 2012; Microsoft Corporation).

Results and Discussion

Ten sediment cores were taken from four sites within Port Everglades and two cores from West Lake south of Port Everglades along the Intracoastal Waterway (ICW). Three cores were taken from Dania Cutoff Canal (DCC), two from South Turning Basin (STB), three from Park Education Center (PEC), and two from Park Headquarters (PHQ). Replicate cores within each site were taken to compare element concentration variations per location as sediments are dynamic systems. All cores were collected along the perimeter of the Intracoastal Waterway within the port and in West Lake (WL) in water depths less than two meters. Reef sites (RF) surface sediment concentrations were compared to the surface concentrations of all cores. Concentrations of all 14 elements were detected in all sediment cores. Table 2 illustrates the total elemental concentrations across each sediment core from greatest to least, while Table 3 demonstrates all elemental ranges, upper continental crust values (Rudnick and Gao, 2003), and TEL and PEL values.

Cobalt, cadmium, mercury, and selenium were consistently in the lowest concentrations across all port sites, West Lake, and the adjacent nearshore coral reef tract. Meanwhile, arsenic, manganese, vanadium, and zinc concentrations were the highest at all port sites, West Lake, and the nearshore reef sites. Chromium was the highest at the nearshore reef sites but not across the port sites or West Lake. Molybdenum was the second lowest element concentration at the reef sites and fifth lowest at West Lake while it was moderately to highly represented at all the port sites.

Elemental Core and Sediment Differences per Location

No significant differences were noted between or among replicate cores at WL or replicate sediment samples from the nearshore reef sites. However, two of the four port sites (DCC, PEC) exhibited significant variability, specifically among tin concentrations. DCC exhibited significant differences among the three duplicate cores in concentrations of cadmium and tin and PEC exhibited significant differences ($p < 0.05$) among concentrations of tin (Appendix Table 2). No significant differences in elemental concentrations were found among the cores collected at PHQ and STB. No significant differences were found between the element concentrations of duplicate cores in WL. No significant differences were found among the element concentrations of the surface sediment samples from either north or south RF. The single factor one-way ANOVA revealed significant mean differences between elemental concentrations of Co, Hg, Mn, and Se (Appendix Table 3). Significant differences between coring locations (Port and WL) and RF sites were not able to be determined due to small sample sizes (i.e., surface sediment samples of only 5 cm in RF sites). The elements (Co, Mn, and Se) with significant differences between Port and WL, $p < 0.006$, 0.0055, and 0.0032, respectively, were all elements that displayed low concentrations with respect to the upper continental crust values (Table 3). Due to the low concentrations of these elements, variance was lower, and therefore the analysis of variance (single-factor one-way ANOVA) was more likely to detect differences between coring locations (Port and WL).

Hg ($p = 0.0002$) did not display concentrations below upper continental crust values (Table 3). The majority of Hg concentrations were not detected (Appendix Tables 4 – 17) and were only measured in spikes (Appendix Tables 5, 7 – 9, 12 – 13, 14 – 15). This may be the reason of the significant difference of Hg concentrations across Port locations and WL.

Comparisons to Continental Crust Values

Of the fourteen elements analyzed (As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Se, Sn, V, Zn), all but nickel and selenium had at least one concentration in the cores that exceeded continental crust values (Table 3). Sediment molybdenum concentrations exceeded those of continental crust (1.5 µg/g) at all port locations but not WL or the RF sites (Appendix Tables 4 - 17). Concentrations in one port location (DCC core 3, 384.5 µg/g) exceeded continental crust values by more than 250 %. Arsenic (entire core), cadmium (entire core), molybdenum (entire core), chromium (35 cm), vanadium (35 cm) were above continental crust values at PHQ. Vanadium and chromium have been previously found to be incorporated into sediments due to adsorption to soluble iron (Fe) oxide grain coatings at the sediment water interface (Loring, 1979). Arsenic, cadmium, copper, mercury, molybdenum, and tin in the sediment from WL exceeded continental crust values. The north and south RF sites had levels of arsenic, copper, and zinc that exceeded levels found in the continental crust, with high levels of copper (28.6 µg/g) and zinc (91.1 µg/g) These concentrations were 1.4 and 1.3 times greater, respectively, than those found in the crust. Arsenic concentrations were anywhere from 1.8 to 5.7 times higher than the background continental crust.

Overall, sediment samples from cores collected within the port displayed the most element concentrations above continental crust values, with one location exceeding background levels for 11 of the 14 elements (PEC, As, Cd, Cr, Cu, Hg, Pb, Mo, Ni, Sn, V, and Zn). WL displayed five of 14 element concentrations above continental crust values (As, Cd, Hg, Mo, and Sn), and north and south RF sites only displayed three of 14 elements (south RF - As, Cu, and Zn); the RF sites had the lowest levels of elemental contaminants.

Geo-accumulation index (I_{geo})

Of the 14 elements analyzed, only arsenic and molybdenum exhibited geo-accumulation values showing moderate to extreme contamination levels. Molybdenum and arsenic displayed contaminated Igeo values in DCC and PHQ core samples, ranging from strongly to extremely contaminated (Appendix Tables 18 - 19). Molybdenum and arsenic within STB cores exhibited moderate to strongly contaminated values (Appendix Table 20). Arsenic and molybdenum exhibited uncontaminated to moderately contaminated values at PEC (Appendix Table 21). Arsenic in WL was the only element to show moderately to strongly contaminated levels (Appendix Table 22). Both RF sites showed uncontaminated to moderately contaminated arsenic levels (Appendix Table 23).

Pollution load index (PLI)

The PLI value explains the overall element pollution within each sediment sample. This approach assesses elements within each sediment core. The DCC site cores had polluted sediments throughout the core. STB had low PLI levels while PEC yielded polluted sediments only at the surface sediment. The PLI at PHQ was below contaminated values. The PLI in WL and the RF sites all showed no signs of contamination (Appendix Table 24).

Potential ecological risk (ERI)

DCC sediment exhibited high to significantly high ecological risk. STB and PHQ sediment exhibited considerable to significantly high ecological risk. PEC displayed low to high ecological risk throughout the cores except for the surface sediment that exhibited significantly high risk. WL exhibited low to considerable ecological risk while the RF sites displayed low to moderate potential ecological risk (Appendix Table 25).

Threshold and Probable Effect Levels (TEL and PEL)

DCC arsenic exceeded both TEL and PEL at all depths, chromium and nickel regularly exceeded TEL while copper was found above TEL levels at one DCC sample and Zn exceeded TEL levels at one sample and PEL levels in another (Appendix Tables 26 - 28). PEC samples exceeded the PEL for arsenic, copper, mercury, nickel, and zinc while exceeding the TEL for copper and zinc. PEL also had most of its high elemental contaminants (Cd, Hg, Pb, Ni, Zn, Cu and As) in its surface sediment (Appendix Tables 29 - 31). Arsenic exceeded the TEL values in PHQ cores while cadmium also exceeded the TEL values in multiple samples (Appendix Tables 32 - 33). Copper found at the STB exceeded the PEL level while arsenic, mercury, and zinc exceeded the TEL and were found primarily at the surface of the cores (Appendix Tables 34 - 35).

Copper and mercury exceeded the TEL in WL samples while arsenic exceeded the TEL values across the WL cores. No PEL values were exceeded by any of the fourteen elements in the WL core samples (Appendix Tables 36 - 37). The only elemental concentration found above the PEL threshold was copper in a single sample at the RF sites; the north RF site had samples containing arsenic concentrations (Appendix Tables 38 - 39).

Comparison of Port, WL, and RF with world-wide Port Elemental Concentrations

Appendix Table 40 displays elemental concentrations of marine sediment at various worldwide Port locations with the Port Everglades data added for comparison purposes. Concentrations of cobalt and nickel were generally lower in the Port Everglades cores (Co 0.02 – 7.40 µg/g and Ni 0.42 – 19.5 µg/g) than those found in previous port studies in New South Wales Australia (Co: 1-12 µg/g and Ni 3-20 µg/g), Naples, Italy (Co: 1.96-7.2 µg/g) and Koper, Slovenia (Ni 61.3-109.4 µg/g). Concentrations of chromium (0.34 – 56.8 µg/g), copper (0.29 – 210 µg/g), mercury (0 – 0.74 µg/g), lead (0.06 – 35.9 µg/g), manganese (1.6 – 203.6 µg/g), selenium (0.05 – 6.8 µg/g), tin (0.0 – 140.1 µg/g), vanadium (0.2 – 176.2 µg/g), and zinc (0.63 – 387 µg/g) were similar to concentrations those found in these studies, while arsenic (0.8 – 223 µg/g), cadmium (0.0 – 0.92 µg/g) and molybdenum (0.0 – 140.1 µg/g) were consistently higher than those found in port sediment in these various locations (Appendix Table 40).

Elemental Contaminants – Dania - Cutoff Canal

The highest concentration of molybdenum was displayed in DCC (384.5 µg/g), 256 times greater than continental crust background levels, Appendix Table 6), and was the highest molybdenum concentration in all the cores (Port, WL, and RF) collected in this study. The range of molybdenum in DCC was not detected (n/d) to 384.5 µg/g. The high concentrations of molybdenum could be due to anoxic and sulfidic conditions in the water column. Molybdenum concentrations in sediment, along with iron (Fe) distribution, is typically used to identify such conditions in marine systems (Scholz, et al. 2017). Molybdenum also has a long residence time of approximately 440,000 years in oxygenated seawater (Miller, et al. 2011), and is converted to sulfur-containing complexes in the presence of dissolved hydrogen sulfide (H_2S) (Helz et al. 1996; Erikson and Helz, 2000; Vorlicek et al., 2004; Dahl et al., 2013a). Therefore, sedimentary Mo enrichments will typically indicate the presence of hydrogen sulfide as well as anoxic conditions (Scholz, et al., 2017). It is possible sediment samples collected from DCC contained anoxic and H_2S sediments due to consistently high levels of Mo in the first 50 cm. Additionally, DCC displayed the highest level of arsenic of all the cores collected within this study, with a concentration of 223 µg/g (Appendix Table 6), 148.7 times greater than upper continental crust values. The range of arsenic in DCC was 0.80 – 233 µg/g.

High concentrations of both molybdenum and arsenic could indicate a significant contamination within the surrounding ecosystem. Significant correlations between the two elements (R = 0.87641) were displayed within DCC as well (Figure 2; Appendix Table 41). Visible evidence of this disturbance, e.g., an obvious separation between sediment and organic material, within the longitudinally split sediment core can be seen in the Appendix Figure 3.

Dania Cutoff Canal is located just south of Port Everglades and is used by small ships handling heavy equipment and general cargo (U.S. Harbors, 2021). Widespread groundwater contamination within Port Everglades has been reported due to storage tank leakage, as well as observations of significant standing petroleum floating and mixing on the groundwater table. The Port Everglades Impact Statement (2015) stated that contamination into the underlying groundwater and adsorption of elements by underlying sediments in Port Everglades and Dania Cutoff Canal is likely; therefore, elements above PEL were to be expected. All other samples for all 14 elements were below the TEL (Appendix Tables 26 - 28).

Elemental Contaminants - Park Education Center

Manganese (98.1 µg/g), vanadium (176.2 µg/g), and zinc (602.8 µg/g) were the highest concentrations found in PEC. Manganese has been associated with mangrove forest rhizospheres and high permeability of sediments (Guieros et al., 2003). Vanadium and zinc are strongly associated with organic matter (Emerson and Huested, 1991; Shine and Ford, 1995; Du Laing et al., 2007; Schneider et al., 2016; Telfeyan et al., 2017). Thus, sediments with higher particulate organic matter are more likely to become contaminated with elements over time through processes such as sorption to humic substances (Liang and Wong, 2003).

The highest concentration of copper was displayed in PEC (214.9 µg/g, 8.6 times greater than continental crust background levels, Appendix Table 8), and had the highest copper concentration of all the cores (Port, WL, and RF) collected in this study. Copper has been used in antifouling treatments since ancient times (Yebra et al., 2004); however, starting at the end of the 18th century, is has been more frequently incorporated along with other metals such as lead, arsenic, and mercury (OSPAR Commission, 2016). This sample site's proximity within central Port Everglades may explain the high concentrations of copper found in surface sediment. The highest concentration of zinc was displayed in PEC (602.8 µg/g, 8.5 times greater than continental crust background levels, Appendix Table 9), was also the highest zinc concentration of all the cores (Port, WL, and RF) collected in this study. Copper and zinc have been previously analyzed in surface sediments in Bahía Blanca Estuary, Argentina, an area that is near oil refineries, terminals, petro-chemical industries, and textile plants that discharge waste into the surrounding estuaries. This area additionally is frequently utilized by fishing boats and cargo ships and requires frequent dredging. Both copper and zinc were detected in surface sediments in Bahia Bay, with zinc displaying a 1.3 times high acute toxicity than copper to recently hatched Chasmagnathus granulate larva, a burrowing semiterrestrial crab (Ferrer et al., 2003).

PEC displayed strong correlations ($R > 0.8$) between the following: molybdenum and arsenic ($R = 0.92858$), copper and lead ($R = 0.8888$), and arsenic and selenium ($R = 0.85846$) (Figure 3, Appendix Table 42). Lead is known to have a high correspondence with reactive solid phases and copper concentrations are strongly affected by the presence of organic matter (Laxen, 1985; Della Puppa et al., 2013; Seda et al., 2016). Additionally, lead has been found to bind to soil particles as well as to living and dead microbial cells (Chaney et al., 2000; Yang et al., 2009). It has also been found in association with copper and iron in freshwater streams in central Indiana (Reising et al., 2018). Anthropogenic sources or arsenic and selenium include coal combustion, mining, smelting, and municipal, industrial, and domestic waste disposal (Wen and Carignan, 2007; Zeng et al., 2015; Ali et al., 2019;). Arsenic and selenium are both metalloids with very similar chemical properties with different biological effects (Sun et. al., 2014). However, little is known about their elemental interactions in sediment.

Elemental Contaminants - Park Headquarters

Element concentrations in PHQ exceeded upper continental crust values (Rudnick and Gao, 2003) for the following: molybdenum (269.5 µg/g, 179.1 times greater than upper continental crust values), cadmium (0.70 µg/g, 7.1 times greater than upper continental crust values), vanadium (70.8 µg/g, 1.18 times greater than upper continental crust values), zinc (241 µg/g, 3.4 times greater than upper continental crust values), chromium (42.8 µg/g, 1.2 times greater than upper continental crust values) and arsenic (75.0 µg/g, 50 times greater than upper continental crust values) (Appendix Tables 10 - 11). Park Headquarters is less than 0.4

kilometers south of Park Education Center, however, it displayed considerably lower element concentrations. It is difficult to determine the cause of such differences, as sediment systems are dynamic and unpredictable. One site may have had more anthropogenic sediment disturbance related to park activities than the other.

PHQ displayed significant correlations (R > 0.8) between the following: molybdenum and arsenic (R = 0.8717), molybdenum and selenium (R = 0.8243), lead and copper (R = 0.8954), vanadium and chromium (R = 0.9150), vanadium and selenium (R = 0.8889), chromium and selenium (R=0.9181), and arsenic and selenium (R = 0.8045) (Figure 4, Appendix Table 43). Although this location displayed many significant interactions between elements, the highest element concentrations found within PHQ were molybdenum (269.5 µg/g, 177 times greater than upper continental crust values) and zinc (241 µg/g, 3.4 times greater than upper continental crust values) (Appendix Tables 10 - 11). Like DCC and PEC, evidence of anoxic conditions, organic matter, and higher likelihood of contamination were displayed at PHQ (Shine and Ford, 1995; Du Laing et al., 2007; Schneider et al. 2016; Scholz et al., 2017).

Elemental Contaminants - South Turning Basin

The highest element concentrations within STB were copper (136.5 µg/g), manganese (101.8 µg/g), and zinc (190 µg/g) (Appendix Tables 12 - 13). Samples collected from the South Turning Basin exceeded upper continental crust values (Rudnick and Gao, 2003) for the following: arsenic (59.9 µg/g, 39.9 times greater than upper continental crust values); cadmium (0.35 µg/g, 3.6 times greater than upper continental crust values), copper (136.5 µg/g, 5.5 times greater than upper continental crust values),lead (28.3 µg/g, 1.4 times greater than upper continental crust values), mercury (0.19 µg/g, 1.9 times greater than upper continental crust values), molybdenum (88.5 µg/g, 59 times greater than upper continental crust values) tin (11.1 µg/g, 2.0 times greater than upper continental crust values), and zinc (190 µg/g, 2.7 times greater than upper continental crust values) (Appendix Tables 12 - 13).

Sediment core samples collected from STB were visibly high in organic matter content (Appendix Figures 9-10), which may explain the higher number of elemental concentrations exceeding upper continental crust values (Rudnick and Gao, 2003), as elements such as arsenic, cadmium, copper, mercury, and zinc have been found to be associated with high particulate organic matter (Coale and Bruland, 1988; Moffett and Dupont, 2007; Bruland, 1989; Donat and Bruland, 1990; Little et al., 2014; DiToro et al., 1990; Gibbs, 1973; Orem et al., 1986; Chin and

Gschwend, 1991; Johansson and Iverfeldt, 1994; Kainz et al., 2003; Mirlean et al., 2003; Wang and Mulligan, 2005). Additionally, STB displayed values exceeding probable effect level (PEL) threshold values for copper (0.36 – 136.5 µg/g, PEL value: 108 µg/g), and South Turning Basin core 1 displayed a single value (10 cm) of arsenic exceeding the PEL threshold (range 3.0 – 59.9 µg/g, PEL value: 41.6 µg/g).

Element distribution and their relationship with organic matter is a crucial component to determining elemental mobility, potential bioavailability, and toxicity to the surrounding aquatic ecosystems (Baran et al., 2019). Copper and zinc are commonly associated with high organic matter content (Shine and Ford, 1995; Du Laing et al., 2007; Schneider et al., 2016), due to slow decompositions rates in the anaerobic conditions (Liang and Wong, 2003). Sediments with high manganese content often occur in anoxic basins (Huckriede and Meischner, 1996).

STB displayed a multitude of significant interactions (Figure 5, Appendix Table 44); the highest Pearson correlations coefficients were found to be between molybdenum and arsenic (R=0.9105), cadmium and lead (R = 0.9597), cadmium and vanadium (R=0.9360), cadmium and chromium (R=0.9394), cadmium and nickel (R = 0.9679), cadmium and zinc (R=0.9449), cadmium and copper (R = 0.9466), lead and nickel (R = 0.9442), lead and zinc (R=0.9835), lead and copper (R = 0.9964), vanadium and chromium (R = 0.9637), vanadium and nickel (R=0.96), vanadium and selenium (R = 0.9755), chromium and nickel (R = 0.9812), chromium and selenium (R = 0.9592), cobalt and selenium (R = 0.9462), nickel and zinc (R = 0.9273), nickel and selenium (R = 0.9287), and zinc and copper (R=0.9840). Arsenic cadmium, copper, lead, molybdenum, and zinc exceeded upper continental crust values (39.9, 3.6, 5.5, 1.4, 59, and 2.7 times greater, respectively) for samples collected from South Turning Basin, all of which have been found to be associated with high organic matter content (Laxen, 1985; Emerson and Huested, 1991; Shine and Ford, 1995; Kaschl et al., 2002; Korshin et al., 2005; Wang and Mulligan, 2005; Du Laing, et al., 2007; Della Puppa et al., 2013; Marks et al., 2015; Schneider, et al., 2016; Seda et al., 2016;Telfeyan, et al., 2017).

Elemental Contaminants - West Lake

Sediment core samples collected from West Lake Park served as the control, as the site is located within a mostly isolated water body west of the Intracoastal Waterway within an enclosed mangrove habitat five miles south of Port Everglades. There is little to no anthropogenic activity since boats are not permitted. The sediment samples provided valuable insight to the degree of contamination within the area. Low to no water movement was observed in this sample site. However, concentrations exceeding upper continental crust values (Rudnick and Gao, 2003) included molybdenum (3.6 µg/g, 2.4 times greater than upper continental crust values), cadmium (0.28 µg/g, 2.9 times greater than upper continental crust values), mercury (0.26 µg/g, 2.7 times greater than upper continental crust values), copper (30.4 µg/g, 1.2 times greater than upper continental crust values), tin (7.7 µg/g, 1.4 times greater than upper continental crust values), and arsenic (21.7 µg/g, 14.5 times greater than upper continental crust values) (Appendix Tables 14 - 15). Even so, elemental concentrations from WL are significantly lower than sediment samples collected from the Port (Appendix Tables 4 – 15).

WL TEL threshold levels were exceeded at only specific depths for mercury (TEL 0.13 µg/g, 45-55 cm WL 1, 40 cm WL 2), nickel (TEL 15.9 µg/g, 75 cm WL 2), copper (TEL 18.7 µg/g, 5 – 10 cm WL 1, 5 cm WL 2), and arsenic (TEL 7.24 µg/g, found consistently throughout both WL 1 and WL 2 cores) (Appendix Tables 36 – 37). Molybdenum concentrations in WL (n/d - 3.61 µg/g) were much lower compared to Port sites (n/d – 140.1 µg/g) (Appendix Tables 4 – 15).

Overall, the sediment core samples collected from the port and WL displayed high correlations between molybdenum and arsenic (R = 0.83629), chromium and nickel (R = 0.84364), chromium and selenium (R = 0.84602), and copper and lead (R = 0.79765) (Figure 6, Appendix Table 45). The highest correlations among elements from WL were between cadmium and lead (R = 0.9239), vanadium and tin (R = 0.9811), chromium and cobalt (R = 0.9081), nickel and tin (R = 0.9715), and arsenic and selenium (R = 0.9608), with the highest elemental concentrations in manganese and zinc (Figure 6, Appendix Table 45). WL is surrounded by mangroves and their rhizospheres can result in increased manganese levels (Guieros et al., 2003). The particulate organic matter located in the upper portion of the cores may explain the high levels of zinc as it is strongly associated with organic matter (Emerson and Huested, 1991; Shine and Ford, 1995; Du Laing et al., 2007; Schneider et al., 2016; Telfeyan et al., 2017).

Elemental Contaminants - North and South Reef

North RF had high arsenic concentrations (up to 8.55 µg/g, 5.7 times greater than upper continental crust values) (Appendix Table 16). North RF displayed significant correlations (R > 0.8) between cadmium and lead (R = 0.9843), cadmium and vanadium (R = 0.9648), cadmium and chromium (R = 0.9968), cadmium and manganese (R=0.9996), lead and vanadium (R =

0.9033), lead and chromium (R = 0.9953), lead and manganese (R = 0.9887), vanadium and chromium (R=0.9405), vanadium and manganese (R = 0.9574), chromium and manganese (R = 0.9986), cobalt and zinc (R = 0.9646), cobalt and copper (R = 0.9988), nickel and zinc (R = 0.9263), nickel and tin (R = 0.9932), and zinc and copper (R = 0.9508) (Figure 7, Appendix Table 46). South RF had correlations between cadmium and cobalt (R = 1), lead and nickel (R = 0.9869), vanadium and arsenic (R = 0.9998), manganese and zinc (R = 0.9999), manganese and copper (R = 0.9989), and zinc and copper (R = 0.9993) (Figure 8, Appendix Table 47).

South RF displayed high arsenic (up to 3.82 µg/g), copper (28.6 µg/g), and zinc (91.1µg/g) concentrations as well (Appendix Table 17). The copper levels were high enough to exceed the TEL threshold of 18.7 µg/g. Although element concentrations were found to be visibly lower in the RF sites compared to both Port and WL, arsenic concentrations were consistently high (up to 5.7 times above the upper continental crust values). in both north and south RF, although lower than Port and WL (Appendix Tables 4 - 17).

There are both natural and anthropogenic sources of arsenic including erosion of arsenic-containing rocks, volcanic eruptions, mining and fracking, coal-fired power plants, trash incineration, arsenic- chromated copper arsenate (CCA) treated wood, cattle-dipping vats, chicken litter, fertilizers, pesticides, soil amendments, and sludges from water treatment plants (Missimer et al., 2018). A major anthropogenic source of copper into the marine environment is from antifouling paints, which are used to coat buoys, ship hulls and underwater surfaces. Additionally, chromated copper arsenate (CCA) is used in treated timbers for decking and piling structures as well (United States Environmental Protection Agency, 2007). Along with copper, the antifouling paint product is dominated by zinc as well (Ytreberg et al., 2016).

Elemental Contaminants Comparisons for all Sites

Overall, sediment samples collected from the Port cores (DCC, PEC, PHQ, STB) displayed higher concentrations of all elements, except As, compared to WL and RF sites (Appendix Tables 4 - 17). As was found to be extremely high within the Port, exceeding PEL thresholds at all four Port sites (DCC, PEC, PHQ and STB). However, As was consistently high in WL, and RF sites, as well, exceeding the TEL threshold in all but one of the sampling sites (south RF).

As and Mo Covariance in Port Sites

All sites revealed that arsenic (As) concentrations (0.6-223.2 µg/g) in all cores exceeded probable effect levels (PEL, 41.6 µg/g), where a large percentage of benthic organisms show a toxic response. Molybdenum (Mo) concentrations (0-384.5 µg/g) in all cores exceed the background continental crust (1.5 µg/g). Excluding West Lake, North Reef, and South Reef, all port cores (DCC, STB, PEC, and PHQ) displayed evidence of covariance between molybdenum and arsenic.

Transfer of arsenic from the water column to marine sediments is associated with iron (Fe) and manganese (Mn) oxyhydroxides and oxides (Tribovillard, 2020). Similarly, molybdenum may be transferred from the water column to sediments through a particulate shuttle effect involving Fe and Mn (Algeo and Lyons, 2006; Algeo and Tribovillard, 2009). Additionally, high molybdenum values have been found in areas bearing manganese oxides (Crusius et al., 1996).

Significant correlations between molybdenum and arsenic (R = 0.87641) were displayed within all three cores collected from DCC (Figure 2, Appendix Table 41). Arsenic displays correlations with molybdenum enrichments in iron shuttling processes and diagenetic cold fluid circulation (i.e., cold seeps). In both cases of particulate iron shuttling and diagenetic fluid circulation, the correlation between molybdenum and arsenic is caused by a strong relationship between these two metals and reactive iron. Iron causes both molybdenum and arsenic to combine within the sediment where they are trapped (Tribbovillard, 2020). Therefore, there is a high possibility of iron within the sediment samples.

Anthropogenic origins of molybdenum in the environment include agricultural and industrial contamination, such fly ash from mine wastes, fossil fuel combustion (Morrison and Spangler, 1992; Zhang and Reardon, 2003) and crop supplementation to counteract molybdenum deficiency in crops (WHO, 2011a). Arsenic has been used extensively in Florida since 1893 as a pesticide in agriculture and later on golf courses (Singleton, 1929; Miller and McBride, 1931; Miller et al., 1933; Deszyck and Sites, 1953; Singleton, 1958; Deszyck and Ting, 1959; Beard, 1998; Cai et al., 2002; Fishel, 2005; and Bencko and Foong, 2017;). Default Soil Cleanup Target Levels (SCTL) for arsenic levels in Florida soils are defined as 2.1 µg/g in residential environments and 12 µg/g in commercial or industrial environments (Chapter 62-777, Florida Administrative Code). Arsenic levels found within this study exceeded not only TEL and PEL thresholds and displayed extreme contamination (geo-accumulation index, potential ecological risk), arsenic concentrations exceeded the Florida SCTL (2.1 µg/g) as well. Average arsenic concentrations in Florida have been reported to be 3 µg/g (Goldberg, 1963); therefore, anthropogenic inputs are significantly contributing to the arsenic contamination found within the sediment core samples.

Another possible contributor to the anthropogenic sources of arsenic found within the sediment cores is past discharges from Wingate Road Municipal Incinerator and Landfill, a site located approximately 5 miles west of Port Everglades. Municipal solid waste was regularly incinerated here from 1954 to 1978. After being added to the Environmental Protection Agency's Superfund National Priorities list in 1990, the site closed 11 years later. Investigations of toxic chemicals, heavy metals and trace elements have been conducted by the Environmental Protection Agency. Previous arsenic detections as early as 1996 were found to be 211 µg/g at the Wingate Road Municipal Incinerator Dump and Landfill site (EPA, 1996). Additionally, a cancer incidence data analysis was conducted in 2016 for communities in the vicinity of the facility (Florida Department of Health and Division of Environmental Health, 1997). Levels of arsenic at the previous Wingate facility were found to be 23 µg/g in soil and ash residue and 46 µg/g in sediment, as well as sediment collected from Rock Pit Lake (south of Wingate) (59 µg/g in 2013 and 12.2 µg/g in 2015) (EPA, 2016).

The combustion of solid waste produces fly ash and bottom ash, which have been found to contain arsenic, cadmium, chromium, lead, and nickel (Chrostowski and Sager 1991). Due to the close vicinity of this site to Port Everglades, it is possible that the high volume of ash produced by the Wingate facility between the years 1954 and 1978 could be one of the root causes of high levels of arsenic across all locations. However, sedimentation rates are variable by location; therefore, it may be difficult to pinpoint exact timelines to which the ash entered the water column and settled into marine sediment.

Along with multiple possibilities of anthropogenic sources, particulate organic matter may play a role as well. Previous case studies have demonstrated that naturally occurring organic matter has the potential to influence the sorption behavior of arsenic. Organic matter can enhance arsenic release by 1) competition for available adsorption sites, 2) formation of aqueous complexes, or 3) change of redox chemistry of the arsenic species and site surfaces (Wang and Mulligan, 2005). High geo-accumulation index levels of tin were found in association with molybdenum and arsenic in all three cores collected from Dania Cutoff Canal (Appendix Table 18); tin has also been used in biofouling paints: In the early 1960s, organotin compounds (commonly in the forms tributyltin, TBT, or triphenyltin, TPhT) were used in paints as a biocide (Dafforn et al., 2011). The tin-containing biofouling paints became popular as they were effective at low concentrations and were used extensively in the 1970s and 1980s. However, negative environmental effects were observed due to their usage, and the organotin compounds were restricted in the late 1980s for use only on vessels less than 25 meters in length. Today, the anti-fouling market is dominated by copper- and zinc-based paints (Ytreberg et al., 2016).

Copper and Zinc Covariance in Port and West Lake Sites

Copper and zinc consistently displayed maximum values at the same depths, mostly surface sediment (5 to 30 cm) in the following cores: Dania Cutoff Canal 1 (174.5 µg/g Cu, 5 cm and 102.0 µg/g Zn, 5 cm), Park Education Center 1 (28.1 µg/g Cu, 55 cm and 33.3 µg/g Zn, 55 cm), Park Education Center 2 (214.9 µg/g Cu, 5 cm and 415.6 µg/g Zn, 5 cm), South Turning Basin 1 (129 µg/g Cu, 20 cm and 190 µg/g Zn, 25 cm), South Turning Basin 2 (136.6 µg/g Cu, 15 cm and 156.6 µg/g Zn, 15 cm), West Lake 1 (30.4 µg/g Cu, 5 cm and 49.8 µg/g Zn, 5 cm), and West Lake 2 (21.1 µg/g Cu, 5 cm and 37.7 µg/g Zn, 5 cm) (Appendix Tables 4, 7, 8, 12, 13, 14, 15).

Copper is both a common marine pollutant and an essential element to marine organisms in trace amounts. At higher concentrations, however, it can have toxic effects on marine organisms (Kim et al., 2008). Particularly, copper can be extremely toxic to coral reefs (Sabdano, 2009). Sabdano, 2009 demonstrated dramatic coral bleaching and death at copper concentrations of 0.1 µg/g. This indicates the potential severity of the much higher levels of copper observed in this study to the nearshore coral reef tracts.

Copper has been known to be strongly complexed to organic material (Coale and Bruland, 1988; Moffett and Dupont, 2007), and is incorporated within some insecticides in Florida (Diepenbrock et al., 2020). Zinc has been correlated to organic material as well, however, to a lesser extent and by weaker ligands than copper (Bruland, 1989; Donat and Bruland, 1990; Little et al., 2014). Due to the relationship among copper, zinc, and organic materials, it has been hypothesized that enrichments of the two elements in anoxic sediments are controlled by both sulphidiation and transfer of organic matter to the sediment (Francois, 1988; Calvert and Pederson, 1993; Brumsack, 2006; Tribovillard et al., 2006).

Both copper and zinc are used in antifouling and anticorrosive paints that protect the hulls of marine ships, and zinc is often associated with increased sewage, wastewater discharge, and increased sedimentary runoff due to rapidly expanding coastal development (Ali et al., 2011). Due to the high ship traffic in proximity to the sampling sites, these factors may be what responsible for the large zinc spikes observed in the sediment samples.

Cadmium in Port Sites

Cadmium concentrations (0-0.92 µg/g) were found above upper continental crust levels at specific depths, Dania Cutoff 1-3, Park Education Center 1-3, Park Headquarters 1-2, South Turning Basin 1-2, with the highest cadmium level found at 130cm in Park Education Center 1, 9.4 times higher than background levels. Park Education Center was the only site with Cd levels above TEL and PEL values (Appendix Tables 29 – 30).

Cadmium is an element of concern due to its toxicity and potential for trophic transfer (Jacob et al., 2013), and it is one of the EPA's priority pollutants due to its bioaccumulation, persistence, and toxicity (Fu and Allen, 1992). Accumulation of cadmium in organisms is of high concern due to its carcinogenic properties and relative toxicity (Waalkes, 2000; Goyer et al., 2004; Satarug et al., 2010).

One common source of cadmium is within mineral phosphate fertilizers, which commonly contains high zinc concentrations as well (Mortvedt, 1996; Lambert et al., 2007). Although little is known about the adsorption of cadmium by sediment, previous studies (Lo et al., 1992) have found that organic matter tends to bind to cadmium and copper, inducing mobility and affects bioavailability.

Mercury in Port and West Lake Sites

Mercury concentration spikes (0-0.63 µg/g) were found above the threshold effect levels (TEL: 0.13 µg/g) in the following cores and depths: Dania Cutoff Canal 2 (20 cm), Park Education Center 1 (135 cm), Park Education Center 2 (80 cm), Park Education Center 3 (125 cm), South Turning Basin 1 (15 cm), South Turning Basin 2 (10 cm), West Lake 1 (55 cm), and West Lake 2 (40 cm) (Appendix Tables 5, 7 – 9, 12 – 13, 14 – 15).

Mercury is listed as a priority pollutant by international agencies of marine environmental protection and is acutely hazardous in estuaries due to their high biologic productivity (Baeyens and Leermakers, 1998; Kannan et al., 1998; Sferra et al.,1999; Harland et al., 2000; Turner et al., 2001). This has additionally been reported for marine mammals such as dolphins, porpoises, and seals (Law et al., 1992). Organic matter has been found to be an important component in controlling the distribution of mercury and other trace elements in bottom aquatic sediments (Gibbs, 1973; Orem et al., 1986; Chin and Gschwend, 1991; Johansson and Iverfeldt, 1994; Kainz et al., 2003; Mirlean et al., 2003).

A study conducted through Simón Bolívar University in Caracas, Venezuela revealed that Porites astreoides exposed to 1.738 µg/g Hg accumulated 89% of the mercury within the zooxanthellae, with the remaining found to have accumulated in the polyps and skeleton. Porites astreoides also experienced a decrease in both zooxanthellae density and protein content per unit surface area (Bastidas and García, 2004). All surface sediment samples collected from the North reef and South reef locations did not contain mercury. This provides a clear baseline of the present conditions of the reef tracts in proximity to Port Everglades.

Potential Impacts to Coral Reefs

The Port Everglades dredging project will most likely present an elemental contaminant threat to the adjacent coral reef species, as most sediment cores collected near the port displayed evidence of elemental contaminant concentrations at dangerous levels. All reef sediment samples (North and South Reef) displayed significantly lower element concentrations compared to sediment core samples from all locations. These locations have provided pre-dredging baselines and will help to understand the full extent of the potential impacts to the reef ecosystems.

Coral reefs are ubiquitous throughout many shallow coastal environments in lower latitudes and are at high risk of rising pollution pressures (Ali et al., 2011). Trace elements are included in the three classes of pollutants that pose a significant risk to coral ecosystems, and various stress responses, including 1) physiological stressors, 2) inhibition or coral fertilization and reduced reproductive stress, 3) decreased settlement and survival of coral larvae, 4) changes in growth and population of zooxanthellae, 5) changes in photosynthesis rates resulting in decrease of coral calcification and growth rates during juvenile polyp stage, 6) increased bleaching, and 7) overall increased coral mortality have been linked to elevated element levels (Kayser, 1976; Esquivel, 1983; Howard and Brown, 1984; Heyward 1988; Abdel-Salam, 1989; Harland and Brown, 1989; Goh, 1991; Falkowski et al., 1993; Reichelt-Brushett and Harrison, 1999, 2005; Reichelt-Brushett and Harrison 2000; Ferrier-Pages et al., 2001; Reichelt-Brushett and Michalek-Wagner, 2005; Mitchelmore et al., 2007; Sabdono 2009).

Laboratory experiments have displayed evidence of chemical contamination posing a threat to corals species; however, it is difficult to pinpoint specific contaminants. Low concentrations of copper, zinc, and iron can physiologically impact coral function at various life These toxic substances, commonly found in antifouling agents, can have severe impacts on corals. Unfortunately, the effects of these elements are “silent”, resulting in chronic and/or sublethal stress or mortality of unknown causes (U.S. Army Corps of Engineers, 2015).

Conclusions

Sediments within the vicinity of Port Everglades contain a variety of potentially harmful elemental concentrations. Trace elements were found in high concentrations at all Port locations but not at the coral reef sites. Contamination spikes (including cadmium, chromium, copper, lead, mercury, nickel, and zinc) throughout the sediment cores suggest possible elemental interactions with high organic matter and/or anthropogenic inputs contributing significantly to element concentrations in sediment. Arsenic (As) consistently exceeded both TEL and PEL threshold levels within the Port, as well as exceeding TEL in WL and RF sites. Additionally, molybdenum (Mo) exceeded upper continental crust values (Rudnick and Gao, 2003) in the Port and WL. However, there has been no TEL or PEL Mo data in the literature to help determine its toxicity to the marine environment; therefore, more studies will need to be conducted to determine the potential toxicity of Mo to benthic organisms. It is likely that the surrounding coral reef ecosystem will be greatly affected by these contaminants once the dredging project begins. The measured port sediment is highly contaminated with arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), molybdenum (Mo), and zinc (Zn), and the high level of water and sediment movement produced during the dredging operation will be much greater than what typically occurs in the shallow Intracoastal Waterway. Due to the high elemental concentrations found within this study, the potential impacts to the nearby reef tracts (coral damage or mortality) could be substantial.

Future Considerations

Along with organic matter, various elements have been found to be directly correlated with iron (Fe) concentrations in marine sediments. The inclusion of Fe in future studies will most certainly aid in the understanding of the origin of element concentrations in sediment samples.

Additionally, future research on the extent of entry and accumulation of elements in marine port sediment would help determine the potential impacts to benthic communities and nearby coral reefs. A separate study to investigate the change in element concentrations post-dredging, as well as incorporating the analysis of persistent organic pollutants (POP), would help to identify the extent of the damage, and possibly to further identify their sources which pose significant threats to the marine ecosystem. Separate studies of temporal accumulation of elements in sediment cores to create a timeline of when contamination occurred would contribute substantially to the discovery of their origin. Sediment traps will need to be placed at the RF locations to observe various types of accumulation and determine possible contaminant sources. Future research will also be needed to determine sedimentary rates, sediment types, and the amount of particulate organic matter (POM) present within the sediment cores.

Table 2. Order of elements from greatest to least based on concentration in each sediment core. DCC = Dania Cutoff Canal, PEC = Park Education Center, PHQ = Park Headquarters, STB = South Turning Basin, WL = West Lake, NR = North Reef, SR = South Reef.

DCC1: Mn > As > Cu > Sn > Zn > V > Mo > Cr > Ni > Pb > Se > Co > Cd > Hg

DCC2: Mn > Sn > As > V > Mo > Cr > Zn > Ni > Cu > Se > Pb > Co > Cd > Hg

DCC3: Mn > Mo > As > Zn > V > Cu > Sn > Cr > Ni > Pb > Se > Co > Cd > Hg

PEC1: Mn > V > Zn > Cr > Cu > As > Pb > Mo > Ni > Sn > Se > Co > Cd >Hg

PEC2: V > Mn > Zn > Cu > Cr > As > Pb > Mo > Ni > Sn > Co > Se > Cd > Hg

PEC3: Zn > V > Mn > Cr > Cu > As > Sn > Ni > Mo > Pb > Co > Se > Cd > Hg

PHQ1: Mo > V > As > Zn > Mn > Cr > Ni > Cu > Sn > Pb > Se > Co > Cd > Hg

PHQ2: Mo > V > As > Mn > Cr > Ni > Zn > Cu > Sn > Pb > Se > Co > Cd > Hg

STB1: Zn > Cu > Mn > V > Mo > As > Cr > Pb > Ni > Sn > Se > Co > Cd > Hg

STB2: Zn > Cu > Mn > V > As > Mo > Pb > Cr > Ni > Sn > Se > Co > Cd > Hg

WL1: Mn > Zn > Cu > As > Pb > Cr > V > Ni > Sn > Mo > Se > Co > Cd > Hg

WL2: Mn > Zn > As > V > Cu > Pb > Cr > Ni > Sn > Mo > Se > Co > Cd > Hg

NR1: Mn > As > V > Cr > Zn > Sn > Pb > Cu > Ni > Se > Co >Cd> Mo > Hg

NR2: Mn > Cr > V > As > Zn > Sn > Pb > Cu > Ni > Co > Se > Cd > Mo > Hg

NR3: Mn > V > As > Cr > Zn > Sn > Pb > Cu > Ni > Se > Co > Cd > Mo > Hg

SR1: Zn > Cu > Mn > Cr > V > As > Sn > Pb > Ni > Se > Co > Cd > Mo > Hg

SR2: Mn > Cr > V > Zn > As > Sn > Pb > Ni > Cu > Se > Co > Cd > Mo > Hg

SR3: Mn > Zn > Cr > V > As > Pb > Sn > Ni > Cu > Se > Co > Cd > Mo > Hg

Table 3. Range of Values of 14 Elements Analyzed (µg/g) compared to Threshold Effect Levels (TEL), Probable Effect Levels (PEL), and Continental Crust Values (Rudnick and Gao, 2003).

Trace Element	Range of Values (µg/g) (cores)	Sediment Quality Assessment Guidelines		Continental Crust
		TEL	PEL	
Arsenic	0.8 – 223	7.24	41.6	1.5
Cadmium	0 - 0.92	0.676	4.21	0.098
Chromium	0.34 - 56.8	52.3	160	35
Cobalt	0.02 – 7.40	NA	NA	10
Copper	0.29 - 210	18.7	108	25
Lead	0.06 - 35.9	30.2	112	20
Manganese	1.6 – 203.6	NA	NA	600
Mercury	0 - 0.74	0.13	0.626	0.098
Molybdenum	0.0 – 384.5	NA	NA	1.5
Nickel	0.42 - 19.5	15.9	42.8	20
Selenium	0.05 - 6.8	NA	NA	50
Tin	0.0 – 140.1	NA	NA	5.5
Vanadium	0.2 – 176.2	NA	NA	60
Zinc	0.63 - 387	124	271	71

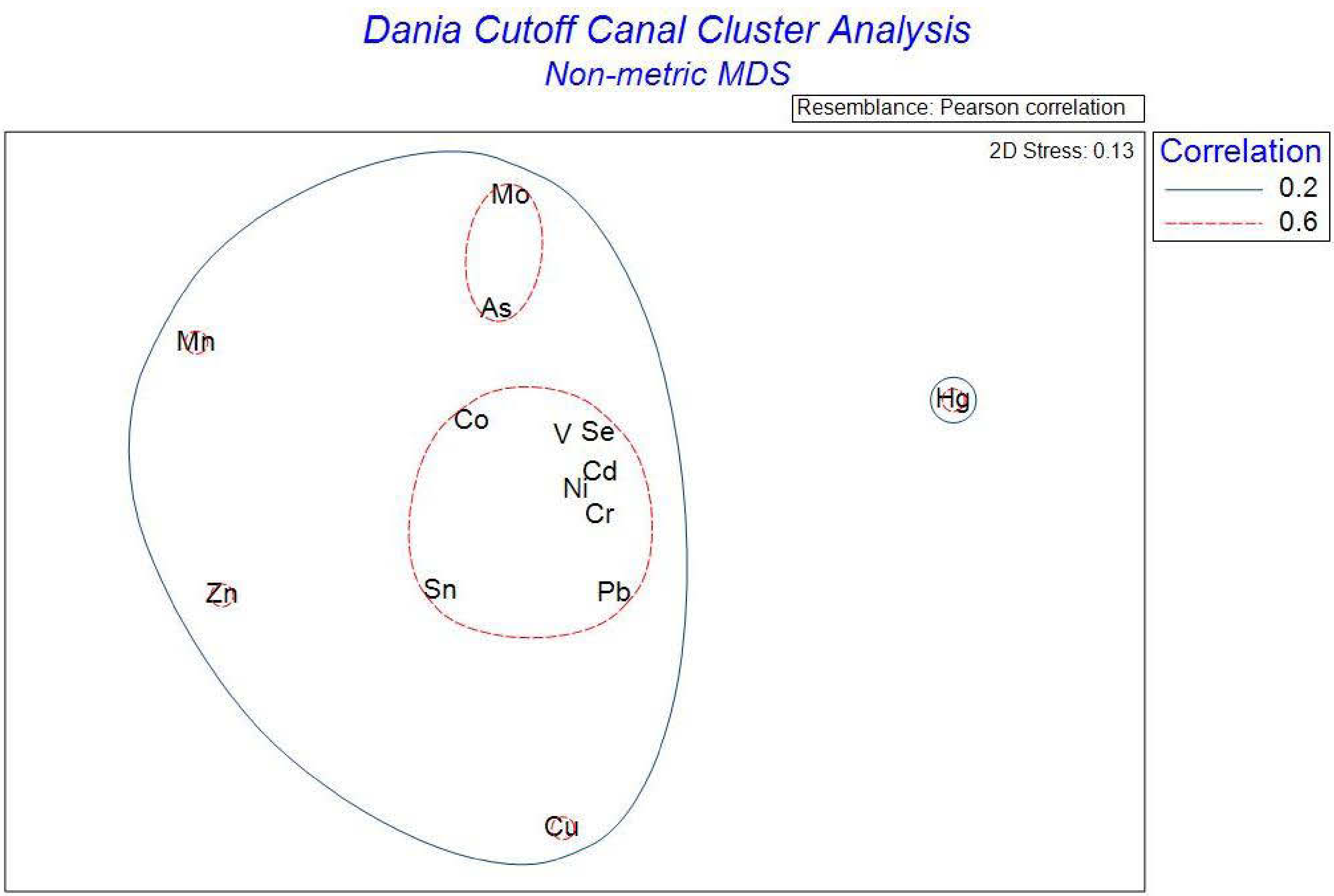

Figure 2. Non-metric multidimensional scaling (MDS) Cluster Analysis of elemental concentrations found within Dania Cutoff Canal categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

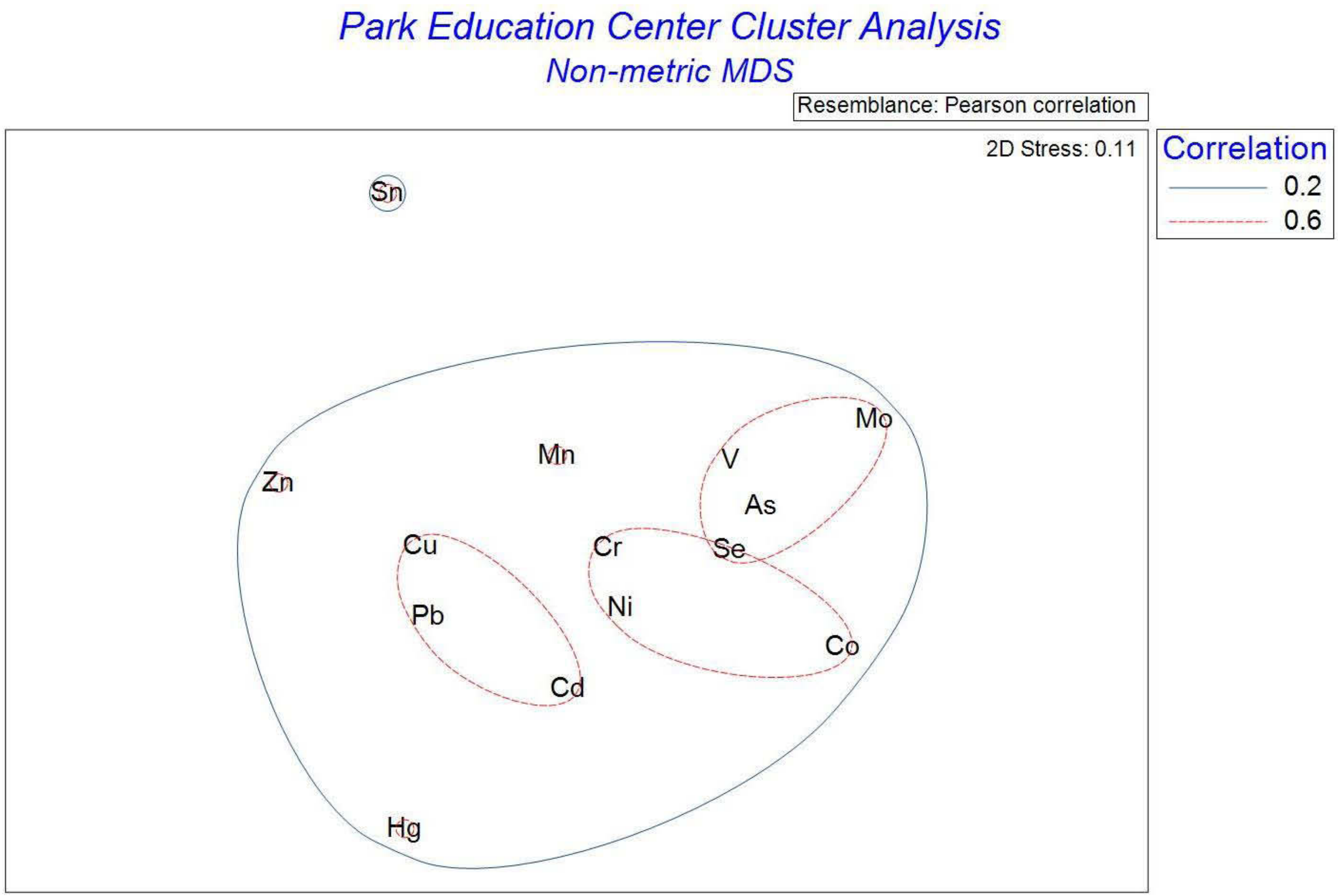

Figure 3. Non-metric multidimensional scaling (MDS) Cluster Analysis of elemental concentrations found within Park Education Center (PEC) categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

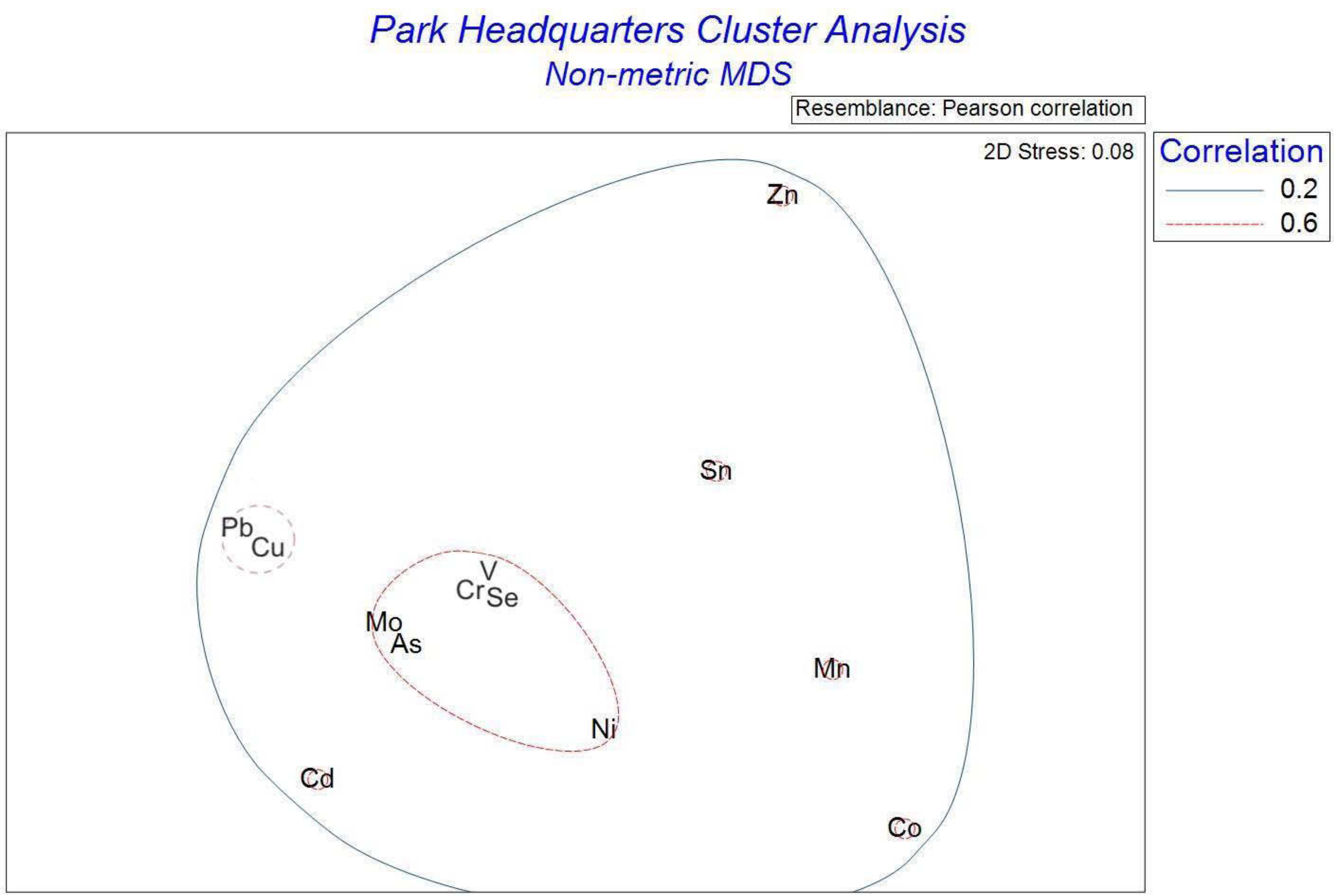

Figure 4. Non-metric multidimensional scaling (MDS) Cluster Analysis of elemental concentrations found within Park Headquarters (PHQ) categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

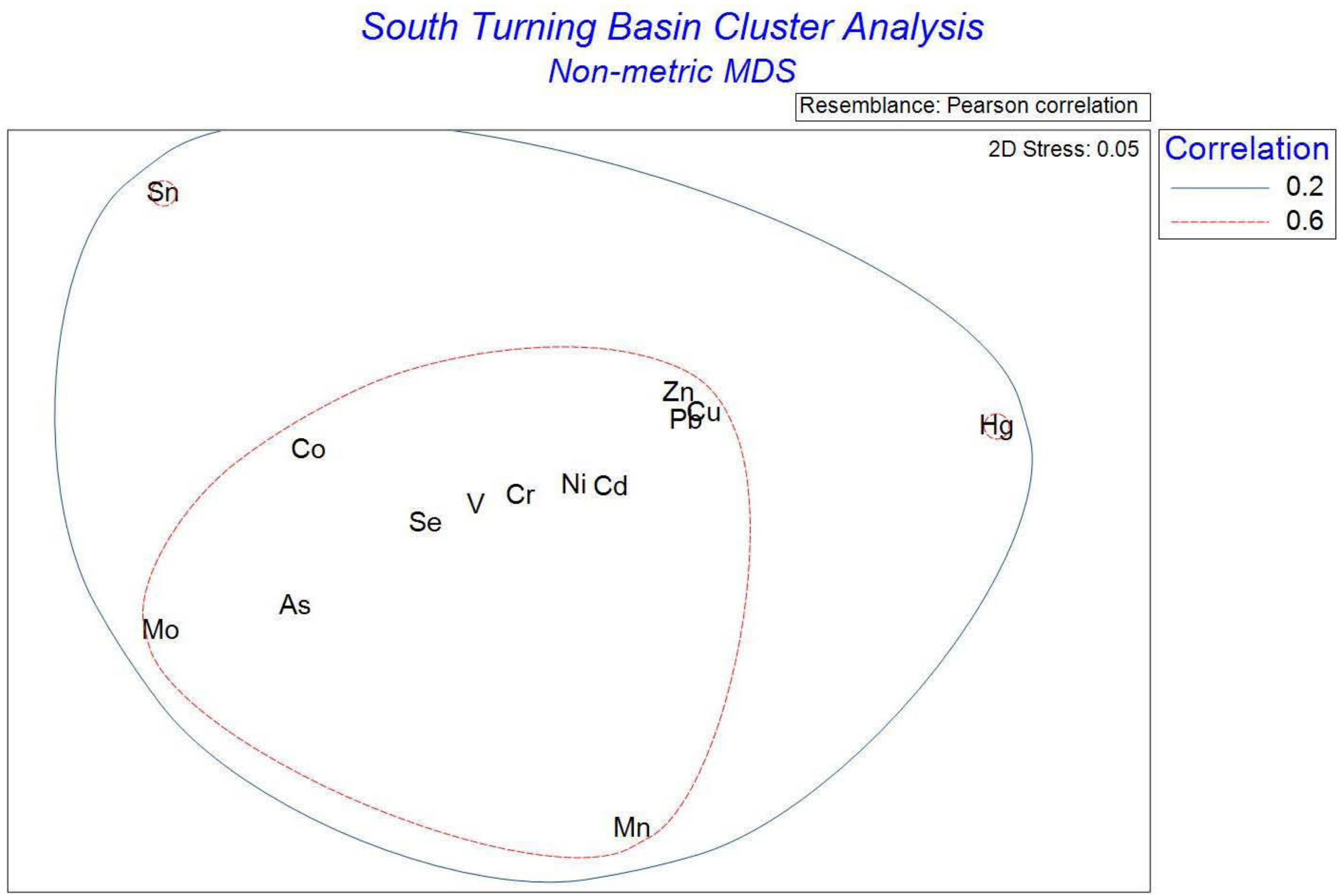

Figure 5. Non-metric multidimensional scaling (MDS) Cluster Analysis of elemental concentrations found within South Turning Basin categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

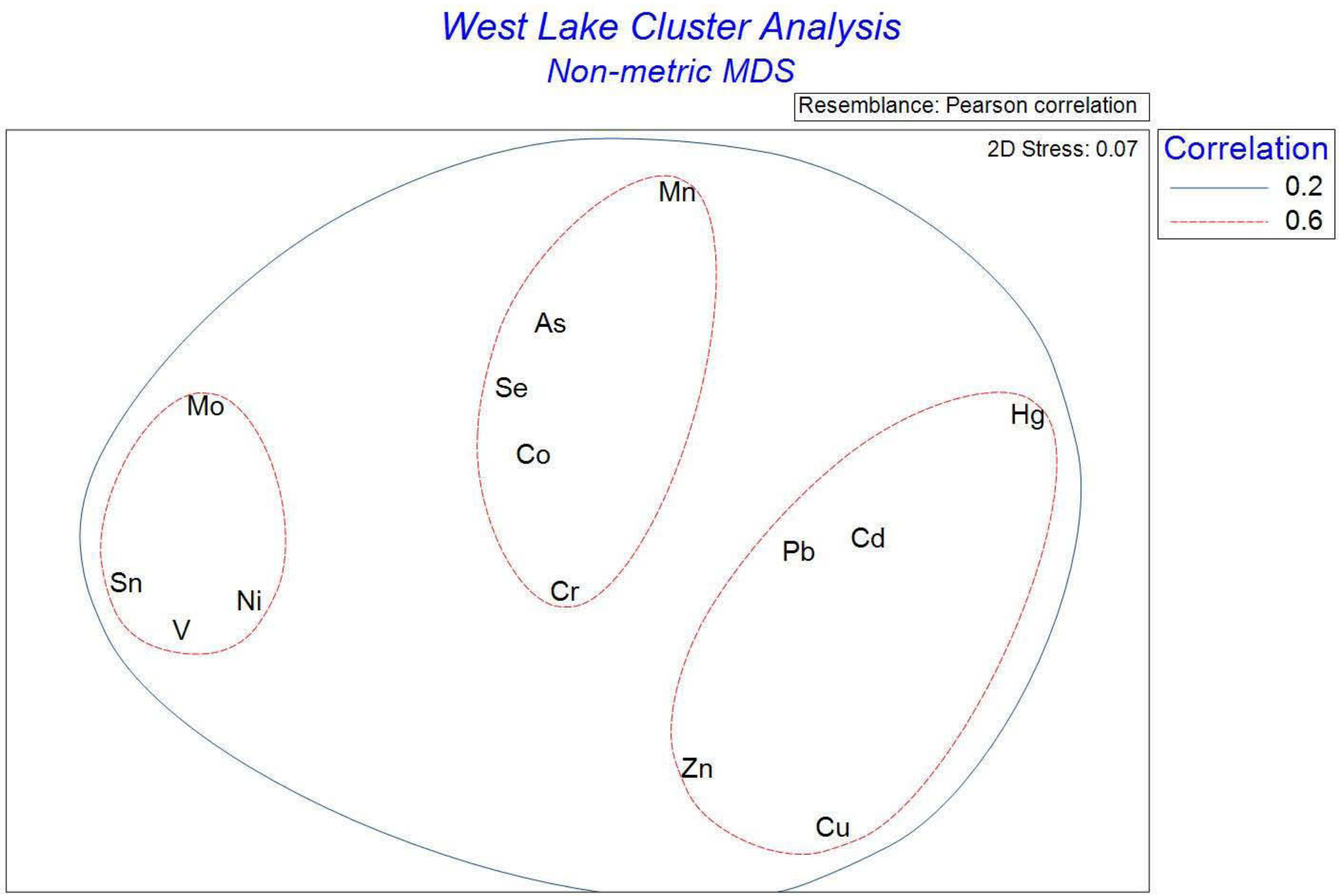

Figure 6. Non-metric multidimensional scaling (MDS) cluster analysis of elemental concentrations found within West Lake, categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

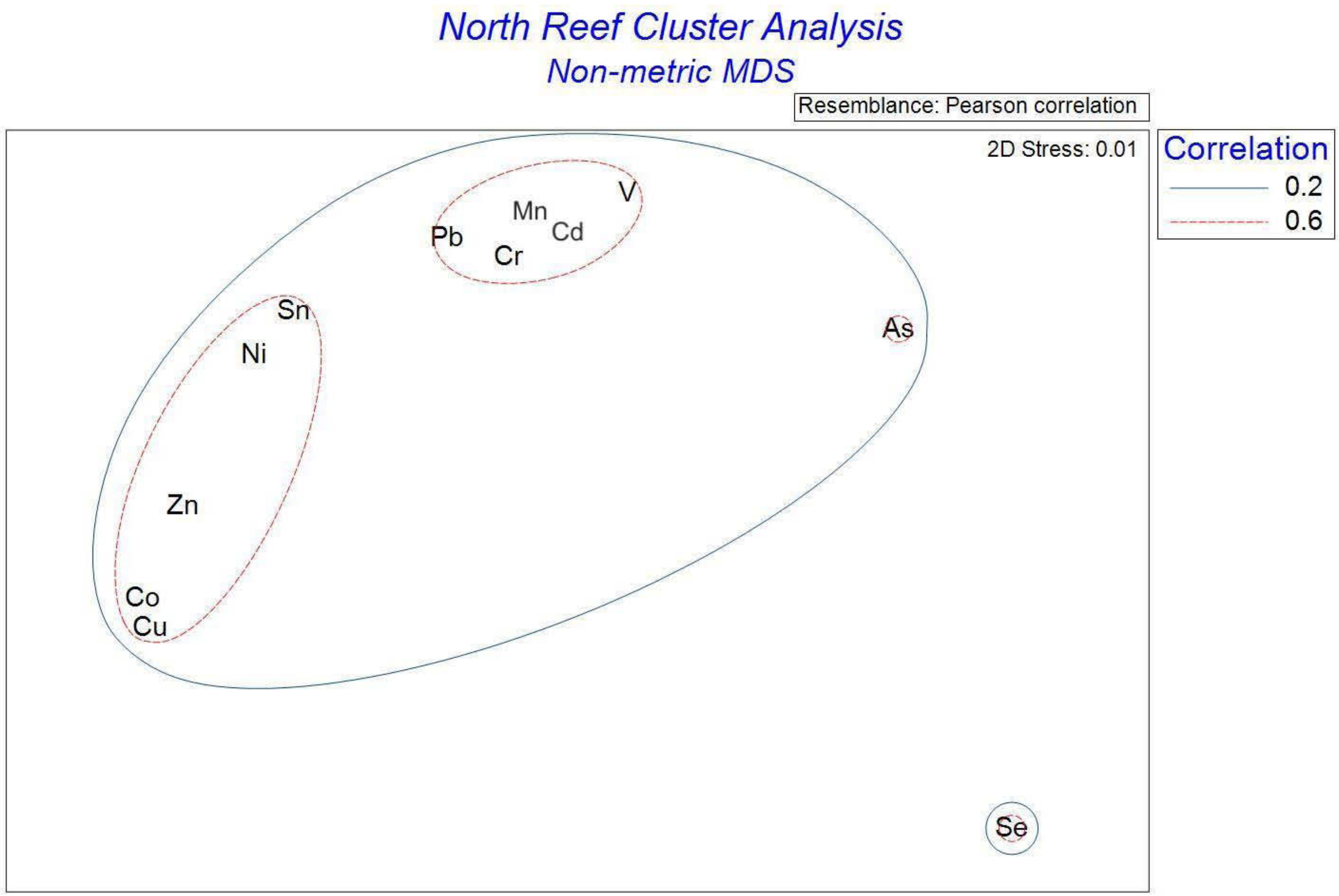

Figure 7. Non-metric multidimensional scaling (MDS) cluster analysis of elemental concentrations found within north RF, categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

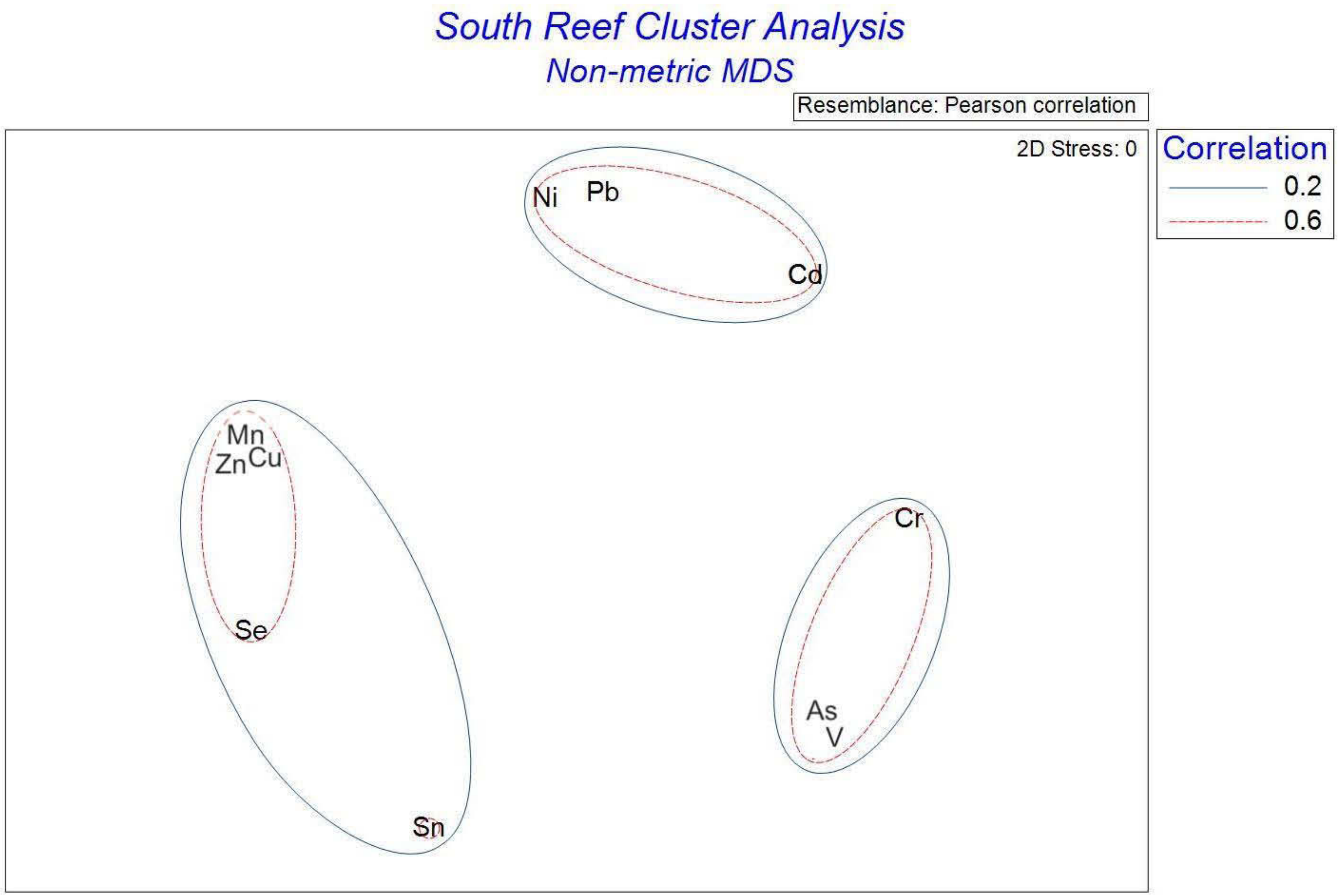

Figure 8. Non-metric multidimensional scaling (MDS) cluster analysis of elemental concentrations found within south RF, categorized by R = 0.2 and R = 0.6 Pearson correlation coefficients.

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Appendix

Appendix Table 1. Inductively coupled plasma mass spectrometer (ICP-MS) detection limits (µg/g) for all 14 elements tested.

Element	Detection Limit
As	0.00003
Cd	0.00001
Cr	0.0001
Co	0.00002
Cu	0.005
Pb	0.0004
Mn	0.00008
Mo	0.0001
Hg	<0.00001
Ni	0.0005
Se	0.00003
Sn	0.001
V	0.00004
Zn	0.02

Appendix Table 2: Paired t-tests. P < 0.05 indicates a significant difference between element concentrations.

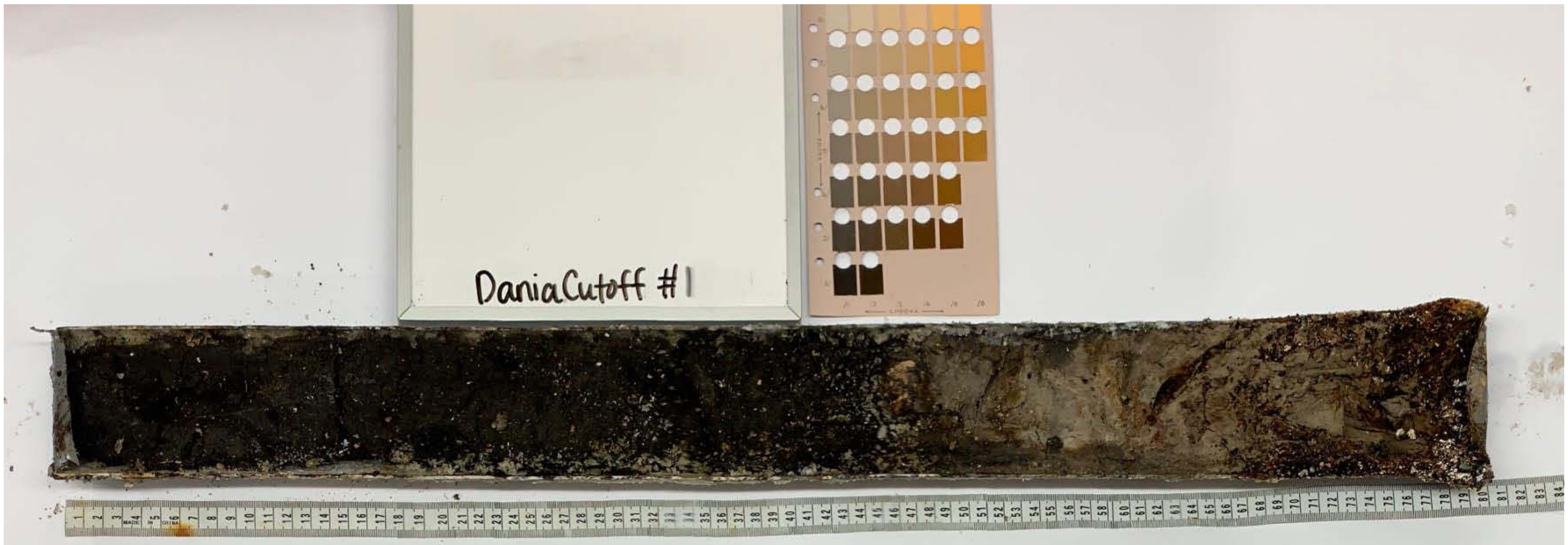
PEC Cores 2, 3	Sn	3.5E-07
PEC Cores 1, 3	Sn	1.6E-05
DCC Cores 1, 3	Sn	0.039
DCC Cores 2, 3	Cd	0.042

Appendix Table 3: Single Factor One-Way ANOVA. $P < 0.05$ indicates a significant mean difference between maximum concentrations amongst coring locations.

Element	P - value
Hg	0.0002
Mn	0.0060
Co	0.0055
Se	0.0032

Appendix Table 4. Dania Cutoff Canal 1 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

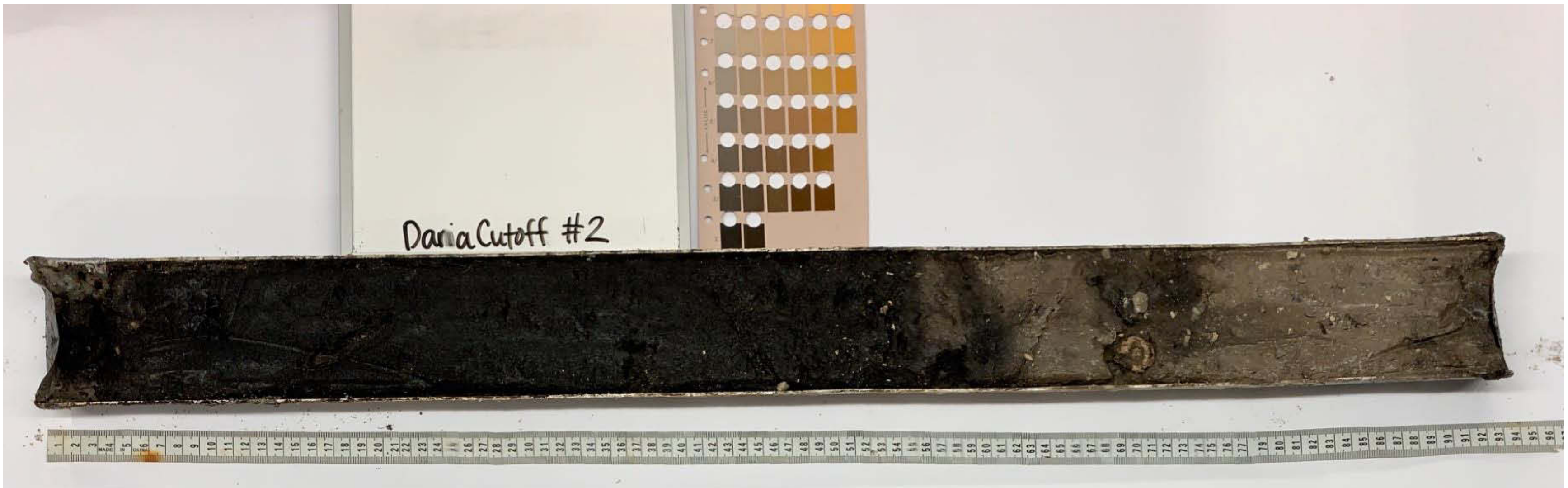
cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	16.1	0.25	n/d	6.35	32.4	34.9	76.2	0.62	11.3	102.0	174.5	52.2	36.4	2.96
10	2.97	0.051	n/d	3.01	7.72	7.41	18.4	0.16	2.26	73.91	150.8	14.8	11.4	0.659
15	20.1	0.17	n/d	2.11	24.8	25.7	48.2	0.47	8.72	9.30	13.40	45.2	42.9	2.30
20	36.3	0.26	n/d	2.00	31.3	22.8	52.4	0.56	8.99	13.1	4.36	54.3	66.2	2.60
25	36.2	0.30	n/d	2.36	37.4	27.8	62.2	0.62	10.1	17.3	20.3	54.5	73.2	2.59
30	24.9	0.19	n/d	1.52	23.3	15.3	43.4	0.47	5.98	4.07	3.51	32.7	53.2	1.70
35	18.7	0.15	n/d	2.72	24.5	14.3	42.3	0.49	5.14	12.5	9.4	24.4	36.3	1.39
40	45.9	0.23	n/d	1.71	38.9	15.4	70.5	0.76	7.29	10.0	23.4	1.03	61.2	2.01
45	17.9	0.080	n/d	1.07	15.0	6.25	63.7	0.51	3.11	5.37	3.70	32.1	26.7	1.14
50	7.06	0.03	n/d	0.23	5.10	1.96	130	0.34	1.23	1.48	0.532	25.3	12.6	0.494
55	3.72	0.01	n/d	0.060	1.25	0.824	119	0.33	0.760	1.01	0.22	16.1	13.5	0.434
60	4.62	0.01	n/d	0.089	2.31	0.788	147	0.29	0.830	1.01	0.381	16.2	14.0	0.458
65	1.91	0.01	n/d	0.15	0.950	0.701	145	0.26	0.523	0.807	0.288	6.13	12.3	0.319
70	0.88	0.01	n/d	0.35	1.13	0.85	163	0.35	0.89	75.4	55.4	1.28	17.9	0.26
75	2.93	0.004	n/d	8.21	5.92	13.6	79.7	1.81	3.57	14.6	10.3	0.05	15.0	0.681
80	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
85	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
90	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.9	0.0	0.0	0.1	0.9	0.7	18.4	0.2	0.5	0.8	0.2	0.1	11.4	0.3
max	45.9	0.3	0.0	8.2	38.9	34.9	162.5	1.8	11.3	102.0	174.5	54.5	73.2	3.0
median	16.1	0.1	0.0	1.7	15.0	13.6	70.5	0.5	3.6	10.0	9.4	24.4	26.7	1.1
mean	16.0	0.1	0.0	2.1	16.8	12.6	84.0	0.5	4.7	22.8	31.4	25.1	32.9	1.3



Appendix Figure 1. Photo of longitudinally split Dania Cutoff Canal Core 1 collected July 9-11, 2019.

Appendix Table 5. Dania Cutoff Canal 2 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

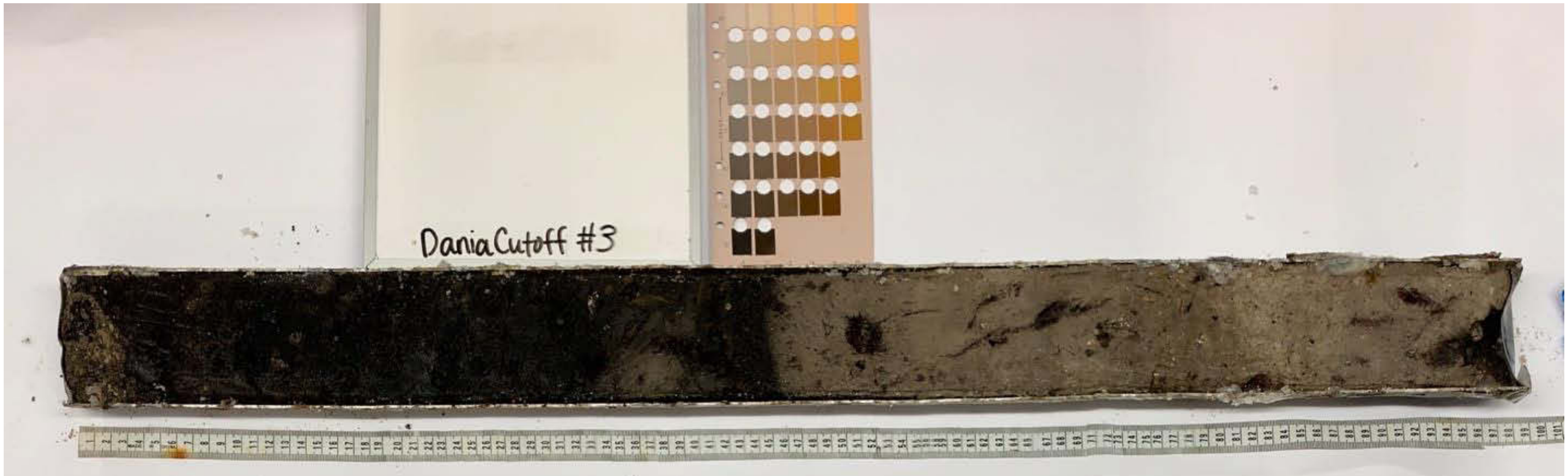
cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.48	0.01	n/d	1.43	2.00	2.01	5.14	0.04	0.47	5.17	3.90	0.730	0.803	0.05
10	45.9	0.46	n/d	4.00	41.5	56.8	47.0	0.92	18.6	10.3	11.9	90.2	44.3	4.55
15	44.1	0.39	n/d	3.62	47.2	51.8	45.2	0.81	16.8	7.82	10.4	140	41.3	4.22
20	44.5	0.43	n/d	4.27	73.9	46.4	75.0	0.88	15.2	28.9	40.7	1.37	56.2	3.56
25	58.3	0.38	n/d	3.88	66.7	53.5	44.7	0.92	19.5	17.5	11.5	131	46.5	4.29
30	62.9	0.48	n/d	3.97	53.7	50.3	60.6	0.85	16.7	10.1	10.2	2.00	72.6	4.79
35	52.4	0.34	n/d	4.15	42.4	37.7	73.7	0.83	14.0	14.3	12.7	106	52.8	2.88
40	60.8	0.40	n/d	3.97	46.0	34.1	63.1	0.87	13.1	19.8	10.9	1.9	80.6	2.90
45	26.8	0.28	n/d	2.63	34.7	21.8	50.5	0.69	9.39	13.8	8.94	59.2	69.6	2.42
50	88.9	0.51	n/d	1.5	100	23.3	63.3	1.25	11.0	242	5.74	81.9	126	2.92
55	8.41	0.03	n/d	0.091	4.02	1.19	103.2	0.33	1.05	0.979	0.36	18.4	17.6	0.57
60	5.50	0.01	n/d	0.10	2.64	0.78	121.1	0.22	0.775	1.10	0.28	20.9	12.8	0.35
65	6.98	0.03	n/d	0.27	3.63	2.60	138.0	0.30	1.64	1.42	0.613	23.3	16.3	0.673
70	19.5	0.24	n/d	2.50	31.4	24.1	75.8	0.56	9.23	5.50	4.72	69.6	55.0	2.14
75	0.570	0.01	n/d	0.036	0.619	0.26	110.8	0.12	0.463	1.67	0.21	12.9	7.79	0.33
80	1.37	0.01	n/d	0.084	1.60	0.502	119.7	0.30	0.542	0.83	0.24	17.9	10.3	0.29
85	0.777	0.00	n/d	0.20	1.25	0.756	99.88	0.18	0.458	0.23	0.1	7.18	14.3	0.399
90	1.59	0.01	n/d	1.38	3.06	3.77	143.0	0.706	1.41	1.36	0.460	7.93	13.8	0.506
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.48	0.00	0.00	0.04	0.62	0.26	5.14	0.04	0.46	0.23	0.12	0.73	0.80	0.05
max	88.89	0.51	0.46	4.58	100.38	56.81	142.98	1.25	19.49	241.93	24.35	140.05	126.02	6.83
median	23.13	0.26	0.00	2.01	33.07	22.54	70.48	0.70	9.31	5.50	5.23	19.61	42.81	2.28
mean	29.47	0.23	0.03	2.13	30.40	22.66	79.56	0.60	8.36	20.81	6.52	44.24	41.02	2.28



Appendix Figure 2. Photo of longitudinally split Dania Cutoff Canal Core 2 collected July 9-11, 2019.

Appendix Table 6. Dania Cutoff Canal 3 Elemental Concentrations (μg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.30	0.10	n/d	5.28	15.5	11.1	14.0	0.24	4.18	41.5	26.1	0.45	18.1	0.849
10	11.8	0.18	n/d	4.77	22.7	9.63	23.9	0.52	5.00	40.6	27.7	0.68	21.2	0.843
15	137	0.02	n/d	2.82	53.1	26.1	10.9	0.31	6.27	54.5	7.61	1.5	52.2	2.812
20	18.2	0.23	n/d	2.45	23.1	7.59	28.88	0.752	4.64	24.0	11.2	0.44	10.6	0.640
25	38.9	0.08	n/d	2.88	14.8	5.26	19.7	0.32	2.39	15.2	12.3	0.50	22.0	0.599
30	129	0.15	n/d	2.16	31.4	6.27	57.0	0.94	3.72	19.6	11.5	1.80	51.1	1.58
35	244.9	0.03	n/d	1.7	37.7	16.3	42.2	0.48	4.60	4.92	4.75	3.03	114	2.85
40	26.1	0.1	n/d	0.31	3.87	2.53	203.6	1.06	1.71	387.1	0.80	1.03	54.3	1.15
45	384.5	0.04	n/d	0.59	17.5	7.12	67.7	0.87	3.60	2.3	3.89	4.18	223	3.94
50	8.17	0.03	n/d	0.080	1.55	0.692	113.0	0.39	0.967	1.32	0.22	0.597	17.8	0.43
55	5.67	0.01	n/d	0.055	0.570	0.427	86.76	0.23	0.504	0.11	0.20	0.31	16.2	0.405
60	0.639	0.00	n/d	0.02	0.16	0.16	110.4	0.19	0.30	0.31	0.063	0.495	6.33	0.31
65	0.34	0.0	n/d	0.02	0.26	0.22	102.5	0.19	0.42	0.36	0.13	0.964	8.12	0.31
70	1.51	0.01	n/d	0.02	0.23	0.23	133.7	0.28	0.60	0.26	0.08	0.867	8.70	0.27
75	0.48	0.0	n/d	0.1	0.23	0.22	127.5	0.47	0.51	0.43	n/d	1.18	14.0	0.24
80	0.22	0.002	n/d	0.03	0.33	0.23	93.03	0.32	0.599	0.46	0.13	13.2	13.3	0.424
85	0.25	0.01	n/d	0.11	0.39	0.42	156.2	0.31	0.670	2.22	0.32	0.720	10.1	0.37
90	0.24	0.0	n/d	0.051	0.35	0.27	108.8	0.477	0.465	0.21	0.083	10.2	12.3	0.22
95	2.10	0.01	n/d	0.077	2.55	0.634	128.1	0.24	0.46	0.547	0.29	25.2	12.5	0.34
100	29.6	0.03	n/d	0.662	4.08	2.08	160.6	0.55	1.18	1.52	0.58	34.4	25.6	0.58
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.22	0.00	0.00	0.02	0.16	0.16	10.92	0.19	0.30	0.11	0.00	0.31	6.33	0.22
max	384.47	0.23	0.00	5.28	53.10	26.14	203.56	1.06	6.27	387.14	27.68	34.41	223.17	3.94
median	8.23	0.02	0.00	0.21	3.21	1.39	97.76	0.35	1.07	1.87	0.45	1.00	17.04	0.50
mean	52.39	0.05	0.00	1.20	11.52	4.88	89.42	0.46	2.14	29.88	5.39	5.09	35.58	0.96



Appendix Figure 3. Photo of longitudinally split Dania Cutoff Canal Core 3 collected July 9-11, 2019.

Appendix Table 7. Park Education Center 1 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.065	0.03	n/d	3.22	3.14	5.30	11.2	0.14	1.25	17.3	12.5	0.11	1.34	0.13
10	0.12	0.028	n/d	1.60	2.34	4.22	5.83	0.10	0.696	8.60	5.00	0.046	0.641	0.06
15	0.743	0.052	n/d	3.61	6.11	6.29	7.89	0.15	1.94	25.7	15.7	0.13	2.01	0.15
20	0.21	0.032	n/d	1.29	2.82	3.55	5.56	0.10	0.725	10.6	3.78	0.035	0.775	0.06
25	1.04	0.048	n/d	3.87	10.1	7.93	9.69	0.22	2.84	17.2	13.2	0.12	2.81	0.17
30	1.18	0.032	n/d	1.92	9.81	9.74	10.4	0.288	2.38	6.88	5.05	0.063	3.93	0.269
35	1.20	0.046	n/d	2.06	11.5	16.6	17.2	0.447	3.00	2.80	1.89	0.00	2.94	0.31
40	1.51	0.052	0.01	4.16	10.5	16.0	22.0	0.532	3.60	5.19	3.60	0.051	4.54	0.30
45	0.444	0.03	n/d	1.50	7.00	12.1	11.8	0.33	2.06	3.65	1.12	n/d	2.97	0.34
50	0.965	0.051	n/d	2.76	10.1	13.2	20.3	0.532	3.14	9.83	2.29	0.01	4.42	0.33
55	3.14	0.34	0.36	20.1	55.0	14.4	30.4	0.747	16.4	33.3	28.1	0.40	12.1	0.61
60	3.86	0.33	0.25	13.7	34.2	11.3	23.6	0.54	10.37	29.9	22.7	0.11	12.1	0.646
65	2.85	0.22	0.29	10.3	16.0	6.70	14.5	0.28	4.53	19.0	15.2	0.22	6.16	0.38
70	2.79	0.24	0.16	8.50	11.6	6.13	15.8	0.23	2.96	16.2	10.5	0.19	5.62	0.27
75	0.886	0.09	0.02	3.39	3.47	2.43	7.36	0.093	1.15	6.66	3.56	0.036	2.10	0.09
80	0.808	0.03	n/d	1.21	1.28	1.30	4.79	0.055	0.399	3.10	1.05	0.02	1.13	n/d
85	1.98	0.03	0.01	2.40	4.50	2.88	11.3	0.13	0.897	6.22	3.23	0.072	3.24	0.16
90	0.484	0.01	0.072	0.971	0.654	1.23	5.34	0.048	0.567	4.07	0.879	0.006	0.850	0.01
95	5.14	0.04	n/d	4.46	7.10	4.98	22.2	0.27	1.63	8.37	6.58	0.28	5.76	0.28
100	9.19	0.13	n/d	9.01	24.0	12.0	34.2	0.50	5.05	21.3	15.5	0.35	11.1	0.76
105	1.32	0.02	n/d	2.61	3.72	2.96	12.4	0.14	1.01	4.30	3.85	0.045	2.80	0.15
110	3.93	0.06	n/d	5.38	10.3	5.84	20.5	0.23	3.12	13.4	3.89	0.37	6.99	0.48
115	4.37	0.088	0.736	3.74	15.0	9.44	35.8	0.37	3.68	10.5	4.13	0.19	11.6	0.817
120	8.14	0.1	n/d	3.52	15.9	7.53	26.8	0.36	2.79	8.59	3.11	0.18	15.4	0.59
125	8.92	0.079	n/d	5.66	15.2	8.45	32.2	0.31	3.27	9.06	3.78	0.055	13.5	0.767
130	43.8	0.92	n/d	3.99	50.7	21.0	20.4	0.67	11.3	6.79	4.97	0.00	32.1	2.26
135	14.1	0.11	n/d	3.98	15.3	6.11	23.3	0.33	2.81	5.26	2.84	0.17	15.8	0.666
140	2.91	0.03	n/d	2.29	7.20	4.16	18.1	0.26	1.51	4.73	1.65	0.12	7.32	0.32
145	2.72	0.03	0.003	1.81	5.24	3.42	17.4	0.14	0.990	3.58	1.31	0.086	3.82	0.23
150	0.789	0.01	0.005	1.28	3.67	2.75	6.89	0.16	0.604	1.55	0.729	0.0038	1.49	0.15
155	0.772	0.01	0.055	3.39	8.76	7.52	9.71	0.517	1.67	1.06	2.1	0.10	0.880	0.35
160	2.28	0.044	0.12	2.10	33.4	7.64	30.5	0.752	2.45	2.81	2.03	0.38	4.01	0.41
165	1.50	0.04	0.048	1.89	22.3	5.64	47.1	0.882	2.47	2.60	3.66	0.14	2.87	0.29
170	1.21	0.03	n/d	1.78	27.7	5.85	41.1	0.67	2.76	11.3	2.92	12.2	2.05	0.14
175	0.43	0.03	n/d	1.39	9.92	4.45	27.3	0.42	1.63	1.24	1.55	0.56	1.11	0.12
180	0.34	0.02	n/d	1.49	8.77	4.86	28.5	0.39	1.77	2.35	1.34	0.17	0.937	0.10
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.065	0.011	0.00	0.971	0.654	1.23	4.80	0.048	0.399	1.064	0.729	0.00	0.641	0.002
max	43.8	0.916	0.736	20.11	55.01	21.0	47.1	0.882	16.4	33.3	28.1	12.2	32.1	2.26
median	1.40	0.041	0.000	2.99	9.99	6.12	17.8	0.296	2.42	6.84	3.63	0.112	3.53	0.285
mean	3.78	0.096	0.060	4.07	13.46	7.38	19.16	0.343	3.04	9.58	5.98	0.473	5.81	0.366

Appendix Figure 4. Photo of longitudinally split Park Education Center Core 1 collected July 9-11, 2019.

Appendix Table 8. Park Education Center 2 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	4.94	0.77	0.24	73.8	59.0	46.6	73.3	2.22	29.3	415.6	214.9	3.27	18.9	1.35
10	0.23	0.053	n/d	4.82	5.16	7.78	14.9	0.25	2.20	25.7	22.2	0.572	1.56	0.16
15	0.11	0.03	n/d	1.84	2.24	4.30	6.63	0.11	0.990	12.3	4.76	1.12	0.61	0.10
20	0.10	0.04	n/d	1.37	2.41	3.39	6.45	0.13	0.800	6.23	2.96	0.687	0.753	0.09
25	1.08	0.1	n/d	3.64	13.8	9.60	11.6	0.32	3.65	9.81	7.22	1.08	2.61	0.22
30	1.37	0.074	n/d	2.45	12.0	12.9	18.9	0.39	3.34	7.55	5.81	0.46	3.21	0.20
35	1.37	0.1	n/d	2.42	12.0	19.7	17.0	0.53	3.40	2.79	1.80	0.30	2.45	0.23
40	0.69	0.1	n/d	2.17	11.7	18.9	16.7	0.43	3.28	3.35	1.55	0.54	2.18	0.13
45	1.50	0.053	n/d	3.47	10.8	17.6	24.6	0.579	3.41	3.88	2.38	0.29	4.64	0.357
50	2.06	0.1	n/d	3.67	11.5	18.9	23.6	0.59	4.19	6.11	3.42	0.54	4.21	0.14
55	1.68	0.046	n/d	2.63	12.3	17.9	18.6	0.543	3.20	2.81	1.83	0.33	3.43	0.31
60	1.05	0.03	n/d	2.06	7.8	11.8	14.0	0.367	2.56	4.33	1.62	0.22	3.59	0.35
65	0.98	0.054	0.01	2.62	10.8	16.4	18.3	0.543	3.14	3.05	2.06	0.26	3.29	0.30
70	3.29	0.20	0.26	9.56	34.2	13.4	25.3	0.589	10.6	16.6	13.8	1.02	8.94	0.613
75	5.50	0.33	0.33	14.0	44.5	11.4	21.6	0.586	12.1	25.0	24.1	1.10	10.4	0.616
80	7.27	0.33	0.632	18.0	31.4	10.3	22.5	0.461	10.1	28.2	25.8	1.10	8.85	0.623
85	4.09	0.28	0.20	10.1	15.2	7.17	16.4	0.28	3.77	18.5	15.5	0.668	8.08	0.530
90	8.71	0.44	0.488	15.6	15.4	9.15	26.1	0.36	3.72	25.6	16.0	0.881	8.24	0.602
95	0.55	0.069	n/d	17.6	1.01	1.84	12.7	0.10	0.61	7.38	2.64	1.12	2.19	0.12
100	0.51	0.04	n/d	1.79	1.23	1.39	6.57	0.06	0.42	3.97	1.40	0.702	1.09	0.03
105	0.60	0.02	n/d	1.31	0.94	1.39	5.73	0.058	0.42	4.26	1.22	1.12	0.804	0.05
110	4.17	0.041	0.01	5.37	14.7	5.71	31.4	0.28	1.70	8.98	9.39	0.429	5.10	0.28
115	6.33	0.071	0.02	3.25	81.06	7.43	30.7	0.25	1.94	14.6	3.65	1.19	11.5	0.525
120	6.64	0.062	n/d	2.88	63.77	7.36	28.1	0.23	1.97	6.49	3.45	0.782	8.09	0.512
125	8.30	0.078	n/d	7.80	49.4	10.1	41.9	0.45	3.25	9.83	6.89	1.17	10.6	0.72
130	89.8	0.24	n/d	1.6	106	13.1	53.4	2.06	4.93	4.04	2.41	3.19	62.4	1.6
135	30.2	0.10	0.1	3.46	176.2	16.8	48.9	0.52	5.13	6.6	3.05	2.44	22.0	1.39
140	6.99	0.065	n/d	6.57	109.9	10.1	45.6	0.37	2.82	7.37	4.04	0.824	8.27	0.548
145	3.13	0.1	n/d	7.99	15.7	7.87	32.3	0.35	2.45	10.0	5.24	0.768	6.75	0.44
150	8.70	0.084	n/d	4.25	43.6	10.7	30.9	0.37	2.96	6.13	4.09	0.802	12.2	0.732
155	0.48	0.01	n/d	0.27	0.927	0.991	2.72	0.03	0.39	0.608	0.054	0.548	1.25	0.056
160	0.24	0.005	n/d	0.24	0.704	0.669	1.96	0.03	0.23	0.709	0.004	0.495	0.799	0.0
165	0.77	0.01	n/d	0.436	1.80	1.34	4.23	0.056	0.443	0.818	0.25	0.13	1.45	0.049
170	2.65	0.03	0.03	1.03	9.88	2.93	18.1	0.33	1.16	1.20	1.10	0.28	3.35	0.10
175	1.74	0.04	n/d	1.67	15.9	5.44	27.4	0.45	1.92	2.91	2.34	n/d	3.86	0.31
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.10	0.00	0.00	0.24	0.70	0.67	1.96	0.030	0.230	0.610	0.00	0.00	0.610	0.00
max	89.8	0.77	0.63	73.8	176	46.6	73.3	2.22	29.3	416	215	3.27	62.4	1.59
median	1.74	0.06	0.00	3.25	12.3	9.60	18.9	0.37	2.96	6.49	3.42	0.70	3.86	0.31
mean	6.22	0.11	0.07	6.90	28.7	10.4	22.8	0.440	3.90	20.4	12.0	0.87	7.36	0.41

Appendix Figure 5. Photo of longitudinally split Park Education Center Core 2 collected July 9-11, 2019.

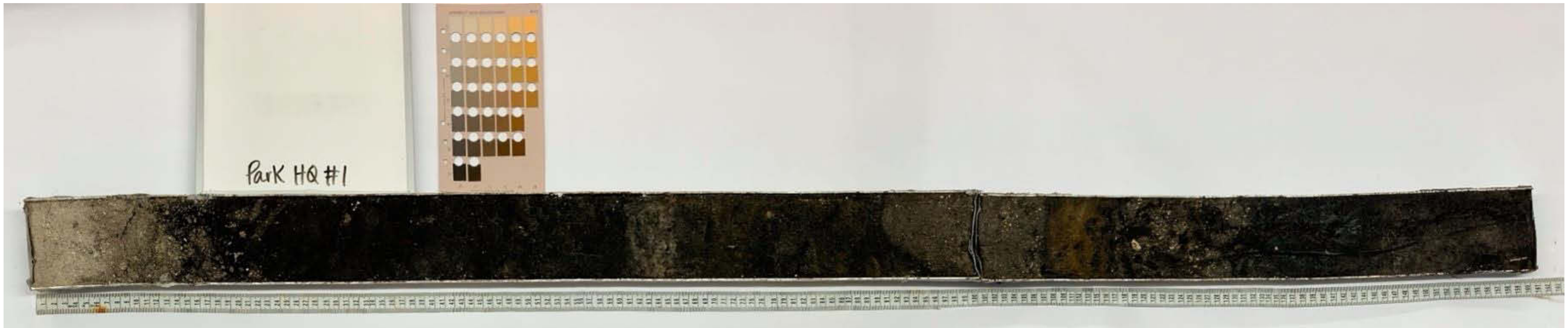
Appendix Table 9. Park Education Center 3 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	10.1	0.39	0.25	35.9	100.4	41.1	98.08	1.23	22.2	225.3	210.2	14.6	22.2	1.25
10	1.50	0.077	n/d	4.24	20.2	13.4	18.8	0.40	5.00	14.6	10.5	11.7	3.75	0.24
15	0.26	0.04	n/d	1.65	5.90	5.41	8.06	0.18	1.67	5.61	3.16	9.83	1.23	0.050
20	0.14	0.03	n/d	1.73	4.25	4.17	5.84	0.13	1.13	7.11	4.61	15.6	1.00	0.00
25	0.12	0.04	n/d	1.69	4.34	4.31	5.75	0.12	1.16	7.50	4.81	11.7	1.04	0.045
30	1.28	0.068	n/d	3.75	15.3	11.4	13.3	0.35	3.99	15.7	11.3	8.68	3.56	0.28
35	0.19	0.03	n/d	1.59	4.59	4.44	6.47	0.12	1.31	602.8	4.36	11.0	0.979	0.581
40	2.08	0.050	n/d	2.31	11.7	13.2	15.3	0.450	2.92	4.05	3.11	4.06	4.12	0.28
45	0.588	0.033	n/d	1.00	6.13	11.0	11.2	0.296	1.74	10.8	0.792	2.74	2.25	0.303
50	1.03	0.03	n/d	1.57	9.66	13.8	13.6	0.408	2.36	1.60	1.43	2.23	3.78	0.502
55	1.30	0.048	n/d	2.16	10.4	14.4	16.1	0.394	2.60	1.60	1.42	2.71	2.49	0.307
60	1.27	0.046	n/d	3.01	10.8	19.4	25.5	0.551	3.36	3.05	2.01	4.34	3.78	0.34
65	1.83	0.075	0.11	6.91	13.0	19.9	27.7	0.624	4.60	14.3	6.95	4.00	4.33	0.478
70	1.90	0.068	n/d	3.08	10.9	17.1	22.3	0.574	3.45	3.01	2.74	3.11	3.97	0.346
75	2.01	0.05	n/d	2.35	10.5	14.5	16.8	0.50	3.02	2.79	1.94	9.88	3.09	0.23
80	1.77	0.058	n/d	3.28	12.1	18.9	18.7	0.551	3.24	3.18	1.97	3.80	3.32	0.32
85	2.42	0.052	n/d	3.09	11.5	16.2	20.5	0.560	3.35	2.89	2.34	4.31	4.01	0.39
90	3.76	0.063	n/d	3.64	17.2	19.7	26.1	0.899	5.37	3.49	2.85	7.37	6.55	0.588
95	4.24	0.1	n/d	3.54	15.1	17.1	26.7	0.908	4.02	4.20	2.54	8.89	6.60	0.400
100	4.51	0.11	0.11	5.11	28.6	13.5	21.2	0.567	6.88	5.69	6.29	6.73	8.32	0.473
105	7.17	0.25	0.29	13.2	38.79	12.0	21.3	0.527	10.1	23.1	22.4	5.96	14.4	0.757
110	6.65	0.29	0.20	10.1	16.6	7.55	15.4	0.29	4.10	19.2	13.7	5.72	7.14	0.470
115	0.750	0.05	n/d	2.15	2.32	1.77	6.02	0.058	0.654	3.82	2.18	8.22	1.50	0.062
120	4.22	0.12	0.14	4.21	7.53	4.07	12.0	0.18	1.53	10.4	4.45	6.33	5.88	0.26
125	8.33	0.13	0.47	6.73	16.3	7.50	26.1	0.33	3.01	22.6	8.82	6.17	12.0	0.50
130	0.79	0.02	n/d	3.14	1.17	1.65	5.73	0.057	0.45	5.60	1.29	7.34	1.21	0.003
135	2.04	0.039	n/d	2.70	10.7	3.72	15.3	0.14	1.21	4.31	2.65	6.51	3.34	0.25
140	10.2	0.10	n/d	5.49	37.4	9.90	28.8	0.38	3.06	8.02	5.10	10.5	10.9	0.923
145	30.1	0.16	n/d	4.55	80.73	16.1	59.2	0.52	4.68	9.23	4.64	15.6	27.8	1.27
150	2.37	0.05	0.04	6.57	9.14	5.77	24.2	0.30	2.14	8.06	4.01	0.574	5.29	0.39
155	0.46	0.01	n/d	1.21	1.67	1.73	7.63	0.1	0.50	1.49	0.67	0.857	1.41	0.00
160	15.6	0.1	n/d	1.91	38.2	14.5	17.0	2.06	17.0	4.95	5.02	1.72	18.9	1.1
165	13.8	0.1	n/d	1.87	45.7	15.7	11.2	3.52	17.0	1.50	5.03	1.2	15.4	1.23
170	7.84	0.10	n/d	3.07	41.6	15.8	10.6	2.41	13.5	1.89	4.76	0.12	10.5	1.16
175	6.81	0.08	0.01	3.24	39.7	13.3	8.60	1.45	9.57	3.03	4.05	0.23	7.43	1.10
180	8.09	0.072	n/d	3.19	46.2	16.1	10.1	2.57	13.3	4.26	4.18	0.10	10.7	1.13
185	6.99	0.089	n/d	3.84	41.7	16.1	10.1	2.13	14.7	2.60	4.07	0.22	9.72	0.940
190	22.1	0.22	n/d	4.78	124.3	32.7	15.2	6.84	20.0	1.91	3.69	0.50	31.5	1.67
195	8.32	0.05	n/d	2.12	24.2	6.39	21.0	1.1	3.69	1.76	1.92	0.26	6.81	0.35
200	0.43	0.01	n/d	1.51	4.94	3.42	16.6	0.35	1.28	2.02	1.1	0.49	1.1	0.1
min	0.122	0.008	0.00	1.00	1.17	1.65	5.73	0.057	0.450	1.50	0.671	0.100	0.979	0.00
max	30.1	0.40	0.50	35.9	124	41.1	98.1	6.80	22.2	603	210	15.6	31.5	1.70
median	2.2	0.1	n/d	3.1	12.5	13.3	15.7	0.5	3.4	4.3	4.0	5.0	4.2	0.4
mean	5.1	0.1	n/d	4.4	23.8	12.5	19.0	0.9	5.6	27.0	9.7	5.6	7.3	0.5

Appendix Figure 6. Photo of longitudinally split Park Education Center Core 3 collected July 9-11, 2019.

Appendix Table 10. Park Headquarters 1 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.39	0.02	n/d	1.50	1.55	2.53	7.86	0.051	0.36	6.65	2.77	0.734	0.958	0.01
10	3.42	0.04	n/d	1.46	4.34	4.09	10.6	0.13	1.23	75.47	2.97	0.820	2.86	0.24
15	40.4	0.1	n/d	2.2	36.1	13.3	11.4	0.2	4.73	16.5	6.96	3.15	11.3	0.95
20	45.0	0.1	n/d	1.5	32.5	12.1	8.42	0.2	4.38	5.97	2.93	3.89	11.4	1.4
25	63.1	0.1	n/d	1.2	48.3	19.5	5.53	0.19	5.51	4.01	2.29	2.66	21.8	1.3
30	269.5	0.18	n/d	2.43	67.2	32.0	14.0	0.33	8.94	6.31	7.50	2.77	75.0	3.69
35	133	0.20	n/d	3.73	47.2	28.3	16.9	0.34	7.70	8.44	7.95	2.29	40.6	3.10
40	37.0	0.1	n/d	1.14	18.6	13.0	8.12	0.13	3.93	5.55	2.89	1.18	10.8	1.17
45	43.2	0.1	n/d	1.51	24.4	15.9	8.34	0.16	3.88	4.27	3.39	1.59	15.1	1.51
50	20.6	0.02	n/d	0.861	17.2	8.72	5.88	0.21	2.82	7.99	1.90	1.01	11.9	0.79
55	28.2	0.03	n/d	0.937	25.2	10.6	5.93	0.11	2.62	1.90	2.42	1.18	15.4	0.89
60	7.05	0.01	n/d	0.40	5.82	4.31	2.71	0.04	1.02	0.895	0.741	0.600	6.04	0.36
65	5.34	0.02	n/d	0.40	4.56	3.91	2.35	0.03	0.906	2.86	0.945	0.574	5.48	0.26
70	5.75	0.057	n/d	0.834	8.40	6.25	7.86	0.10	1.92	1.65	1.37	0.52	7.85	0.37
75	8.38	0.070	n/d	0.685	11.3	8.77	7.83	0.13	2.80	1.33	1.22	0.53	10.1	0.618
80	7.10	0.11	n/d	0.818	9.17	8.47	9.27	0.15	2.66	39.3	1.48	0.19	10.9	0.487
85	7.92	0.11	n/d	0.772	10.5	8.65	8.72	0.13	2.71	0.852	1.11	0.39	11.5	0.515
90	5.17	0.067	n/d	0.671	7.73	6.60	9.85	0.10	1.76	1.74	0.791	0.458	11.6	0.38
95	4.79	0.046	n/d	0.447	4.96	4.69	6.09	0.072	1.10	0.741	0.404	0.379	9.29	0.27
100	3.73	0.04	n/d	0.805	4.25	3.68	4.58	0.068	1.03	3.84	0.731	0.538	6.98	0.14
105	10.8	0.11	n/d	1.08	14.9	11.0	12.9	0.16	2.56	1.72	1.07	1.07	17.5	0.50
110	15.6	0.053	n/d	0.454	10.9	5.96	7.24	0.11	1.54	1.41	0.590	0.431	14.5	0.35
115	13.0	0.11	n/d	0.719	18.0	9.47	9.69	0.16	2.94	1.28	0.891	0.466	19.1	0.605
120	9.89	0.052	n/d	0.512	14.5	6.55	8.21	0.11	1.47	1.34	0.494	0.544	18.4	0.442
125	9.10	0.052	n/d	0.609	7.49	5.05	7.72	0.12	1.33	0.815	0.415	0.384	13.7	0.26
130	6.97	0.04	n/d	0.42	10.0	4.99	7.22	0.091	1.17	1.20	0.26	0.724	8.26	0.34
135	28.0	n/d	n/d	0.41	47.3	20.6	16.9	0.71	4.92	241	0.79	7.21	16.6	1.9
140	48.7	0.1	n/d	0.32	55.7	19.3	17.6	0.60	4.57	1.7	0.86	3.35	22.4	1.5
145	19.4	0.03	n/d	0.1	25.7	11.1	37.2	1.0	3.23	1.91	0.67	2.68	18.1	1.0
150	11.7	0.02	n/d	0.15	13.0	7.34	30.2	7.40	11.5	7.31	0.63	2.38	16.9	1.05
155	6.92	n/d	n/d	0.20	5.95	3.38	30.0	3.27	12.1	2.35	0.19	2.58	7.58	0.43
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.390	0.00	0.00	0.110	1.55	2.53	2.35	0.030	0.360	0.740	0.190	0.190	0.960	0.010
max	270	0.20	0.00	3.73	67.2	32.0	37.2	7.40	12.1	241	7.95	7.21	75.0	3.69
median	10.8	0.1	0.0	0.8	13.0	8.7	8.3	0.1	2.7	2.4	1.1	0.8	11.6	0.5
mean	29.7	0.1	0.0	0.9	19.8	10.3	11.2	0.5	3.5	14.8	1.9	1.5	15.2	0.9



Appendix Figure 7. Photo of longitudinally split Park Headquarters Core 1 collected July 9-11, 2019

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Appendix Table 11. Park Headquarters 2 Elemental Concentrations (μg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.081	0.01	n/d	1.87	2.12	2.27	13.1	0.082	0.66	8.22	3.71	0.960	0.933	0.05
10	0.17	0.01	n/d	1.93	2.09	1.93	10.5	0.1	0.53	7.48	4.38	1.05	1.05	0.01
15	n/d	0.01	n/d	1.61	1.85	2.75	9.67	0.1	0.50	7.59	3.46	1.37	0.77	n/d
20	33.4	0.16	n/d	4.21	34.7	21.5	18.8	0.37	8.77	9.27	5.28	1.96	14.4	2.07
25	65.9	0.49	n/d	2.97	44.2	20.4	21.7	0.52	11.8	7.02	5.11	1.67	24.4	2.09
30	54.1	0.55	n/d	2.19	31.3	12.2	17.4	0.37	5.41	6.85	4.01	1.25	17.8	1.27
35	96.3	0.70	n/d	2.69	70.8	42.8	14.9	0.59	18.6	3.14	3.01	2.0	26.3	2.63
40	35.2	0.17	n/d	0.793	15.7	9.07	5.54	0.14	3.44	0.605	1.68	0.783	11.1	0.863
45	119	0.1	n/d	1.0	30.7	13.7	7.61	0.22	4.00	4.44	2.54	1.73	32.5	1.60
50	25.0	0.15	n/d	0.694	16.2	9.93	6.18	0.15	3.86	1.48	1.92	0.694	11.4	0.882
55	21.5	0.17	n/d	0.630	22.9	9.84	6.43	0.21	4.42	1.33	1.88	0.729	11.0	0.831
60	15.4	0.065	n/d	0.539	15.7	6.92	3.78	0.094	2.23	0.866	1.47	0.572	9.53	0.631
65	14.5	0.14	n/d	0.745	19.5	10.4	6.15	0.15	4.08	3.59	1.95	0.658	10.6	0.842
70	5.50	0.01	n/d	0.35	5.60	3.67	1.61	0.02	0.72	0.54	0.56	0.869	5.60	0.32
75	6.92	n/d	n/d	0.51	3.88	4.39	2.26	0.03	0.734	0.71	0.63	0.67	5.58	0.32
80	13.1	0.02	n/d	1.08	8.77	10.7	5.42	0.1	1.44	1.20	1.53	1.02	14.2	0.81
85	10.6	0.03	n/d	1.03	8.58	10.5	3.86	0.11	1.59	2.97	1.96	0.81	12.7	0.66
90	16.9	0.04	n/d	1.37	15.6	17.9	9.57	0.14	2.95	5.69	2.97	0.62	20.0	0.933
95	8.98	0.01	n/d	0.815	6.27	8.59	3.38	0.059	1.11	2.49	1.67	0.27	13.5	0.555
100	6.95	0.004	n/d	0.652	5.07	6.68	2.28	0.044	0.804	0.28	1.09	0.22	11.6	0.373
105	7.27	0.01	n/d	0.596	6.25	6.66	2.54	0.05	0.698	0.935	0.707	0.567	11.1	0.35
110	13.2	0.19	n/d	0.990	10.9	10.2	22.8	0.29	4.80	2.15	1.14	0.867	19.5	0.51
115	9.38	0.070	n/d	0.734	7.17	7.60	11.7	0.11	1.96	2.05	0.745	0.874	13.9	0.37
120	37.5	0.04	n/d	1.05	18.6	11.4	4.94	0.087	1.87	0.816	1.46	0.44	30.1	0.808
125	25.1	0.054	n/d	0.810	25.6	11.4	5.14	0.10	1.95	2.27	1.29	0.34	30.4	0.887
130	27.0	0.075	n/d	0.889	15.2	12.4	8.25	0.15	2.33	1.31	1.17	0.59	22.6	0.613
135	21.3	0.1	n/d	1.17	10.4	9.58	7.77	0.13	1.85	0.919	0.70	0.72	23.9	0.43
140	40.3	0.03	n/d	0.33	52.0	21.7	34.1	0.83	4.55	0.40	0.96	2.62	20.1	1.61
145	33.3	0.05	n/d	0.45	38.9	19.4	21.8	0.92	6.20	16.2	1.2	3.40	20.6	1.86
150	7.35	0.04	n/d	0.36	10.2	6.18	7.00	0.40	2.65	2.69	0.67	1.39	8.27	0.68
155	23.5	0.04	n/d	0.24	24.9	14.0	14.0	1.8	6.22	4.09	1.0	4.71	15.6	2.00
160	20.2	0.1	n/d	0.29	15.8	23.8	27.3	2.26	8.23	1.4	1.65	3.23	19.5	1.85
165	21.2	0.02	n/d	0.1	12.8	9.79	16.7	1.4	10.5	0.32	1.2	4.59	12.8	1.7
170	3.06	0.00	n/d	0.03	2.38	2.22	43.5	0.32	3.29	0.31	0.31	1.28	5.01	0.52
175	1.78	n/d	n/d	0.04	1.61	1.45	33.1	0.22	2.57	0.16	0.10	0.853	5.22	0.37
180	1.63	n/d	n/d	0.1	1.95	1.68	34.0	0.32	3.65	0.15	0.31	1.01	3.96	0.27
185	2.98	0.01	n/d	0.25	2.88	2.66	28.5	0.45	7.72	0.32	0.78	2.13	4.99	0.33
190	4.52	n/d	n/d	0.85	4.58	4.10	14.3	0.24	9.56	3.33	0.975	1.71	4.14	0.56
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.00	0.00	0.00	0.032	1.61	1.46	1.61	0.024	0.500	0.147	0.101	0.215	0.769	0.00
max	119	0.697	0.00	4.21	70.8	42.8	43.5	2.26	18.7	16.2	5.28	4.71	32.5	2.63
median	15.0	0.0	0.0	0.8	11.9	9.8	9.6	0.2	3.1	1.8	1.4	0.9	12.7	0.7
mean	22.4	0.1	0.0	1.0	16.4	10.6	13.4	0.4	4.2	3.0	1.8	1.3	13.9	0.9

Appendix Figure 8. Photo of longitudinally split Park Headquarters Core 2 collected July 9-11, 2019.

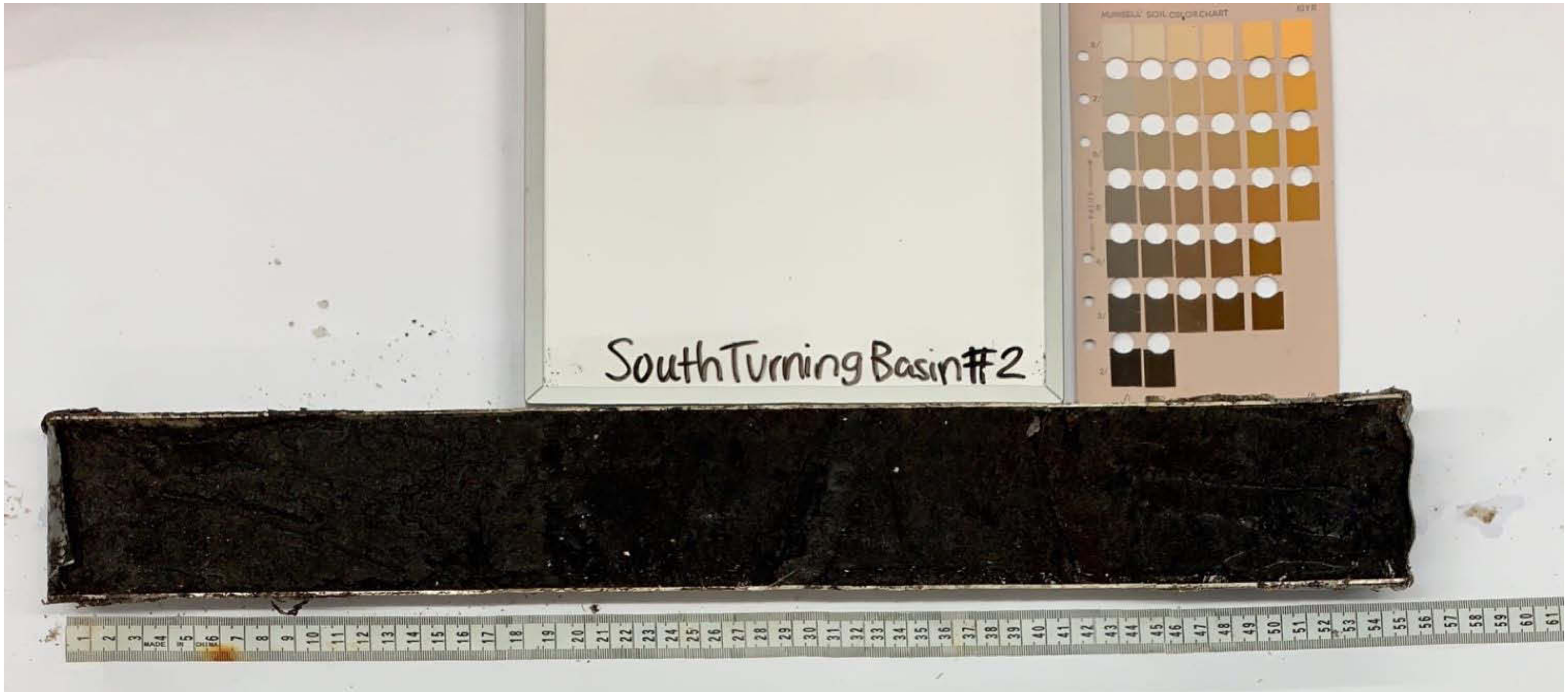
Appendix Table 12. South Turning Basin 1 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.25	0.17	n/d	19.2	25.8	15.0	28.8	0.55	9.43	134	110	2.73	21.5	1.2
10	88.5	0.25	n/d	8.06	45.7	15.8	23.3	0.85	7.74	55.7	42.2	3.77	59.9	1.9
15	17.24	0.33	0.1	27.1	40.1	19.8	45.4	0.89	15.4	150.7	127	3.01	21.5	1.69
20	14.9	0.33	0.03	27.0	37.7	19.2	57.4	0.91	15.4	180	129	4.03	20.9	1.4
25	16.4	0.30	n/d	21.7	51.7	17.6	62.3	1.1	15.9	190	104	4.16	22.8	1.8
30	31.88	0.29	0.1	16.5	43.3	13.4	59.9	0.98	12.6	91.1	67.2	5.04	37.7	1.9
35	25.38	0.15	n/d	9.47	29.0	11.2	45.4	1.1	8.53	61.3	48.4	3.15	31.7	1.65
40	25.98	0.16	n/d	9.57	31.1	17.2	38.7	0.78	10.2	49.9	39.3	3.00	21.3	1.61
45	24.99	0.1	n/d	5.48	28.2	17.6	29.6	0.99	10.4	23.3	18.4	3.89	16.6	1.8
50	44.83	0.1	n/d	1.7	32.6	14.1	18.7	1.5	8.29	5.95	2.4	4.73	18.7	2.0
55	29.68	0.1	n/d	1.8	33.8	9.05	11.3	1.4	6.31	5.81	5.70	4.02	15.7	1.5
60	17.67	0.2	n/d	9.11	29.6	12.5	63.9	0.99	8.32	45.4	45.3	2.26	21.3	1.40
65	4.85	0.04	n/d	1.17	7.40	4.5	63.28	0.5	1.9	9.60	4.10	1.00	14.6	0.800
70	0.074	0.004	n/d	1.01	2.83	2.98	101.8	0.21	1.30	0.627	0.69	0.18	3.01	0.377
75	0.45	0.01	n/d	1.70	7.71	4.73	89.53	0.51	2.22	2.06	1.14	0.082	4.78	0.41
80	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
85	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
90	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.1	0.0	0.0	1.0	2.8	3.0	11.3	0.2	1.3	0.6	0.7	0.1	3.0	0.4
max	88.5	0.33	0.06	27.1	51.6	19.8	102	1.50	16.0	190	129	5.04	59.9	2.05
median	17.7	0.2	0.0	9.1	31.1	14.1	45.4	0.9	8.5	49.9	42.2	3.2	21.3	1.6
mean	23.4	0.2	0.0	10.7	29.8	13.0	49.3	0.9	8.9	67.0	49.6	3.0	22.1	1.4

Appendix Figure 9. Photo of longitudinally split South Turning Basin Core 1 collected July 9-11, 2019.

Appendix Table 13. South Turning Basin 2 Elemental Concentrations (µg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.67	0.26	0.12	22.6	30.5	17.2	38.8	0.67	12.7	132.5	115.0	2.80	15.5	1.33
10	9.75	0.34	0.19	27.4	37.5	20.2	49.3	0.76	15.9	155.8	135.3	3.71	15.1	1.61
15	9.49	0.35	0.16	28.3	39.4	20.3	44.7	0.78	16.4	156.6	136.5	2.95	13.9	1.67
20	14.5	0.08	n/d	5.07	16.7	5.86	17.7	0.52	5.11	22.3	35.0	8.14	15.6	0.30
25	8.97	0.04	n/d	0.64	6.85	5.82	4.07	0.46	2.5	11.6	1.3	4.52	9.11	0.46
30	3.05	0.051	n/d	5.09	6.81	3.45	8.55	0.16	2.59	27.7	22.8	1.03	4.73	0.25
35	9.84	0.04	n/d	0.48	8.4	4.6	3.4	0.6	2.0	5.00	1.20	8.60	12.6	0.50
40	8.57	0.0	n/d	0.69	5.06	3.0	8.33	0.62	1.8	8.32	2.6	7.19	14.5	0.42
45	14.6	0.05	n/d	0.83	7.49	2.6	4.1	0.71	1.3	23.7	1.7	10.3	14.5	0.63
50	14.8	0.1	n/d	0.26	6.76	2.80	5.31	0.66	1.5	4.47	0.36	11.1	13.3	0.41
55	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
65	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
70	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
80	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
85	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
90	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	3.05	0.00	0.00	0.26	5.06	2.64	3.39	0.16	1.33	4.47	0.36	1.03	4.73	0.25
max	14.8	0.35	0.19	28.3	39.4	20.3	49.2	0.78	16.4	157	137	11.1	15.5	1.67
median	9.5	0.1	0.0	0.8	7.5	4.6	8.3	0.7	2.5	23.7	2.6	4.5	13.9	0.5
mean	9.7	0.1	0.1	9.6	16.5	8.9	18.5	0.6	6.3	58.4	46.3	5.8	12.6	0.8



Appendix Figure 10. Photo of longitudinally split South Turning Basin Core 2 collected July 9-11, 2019.

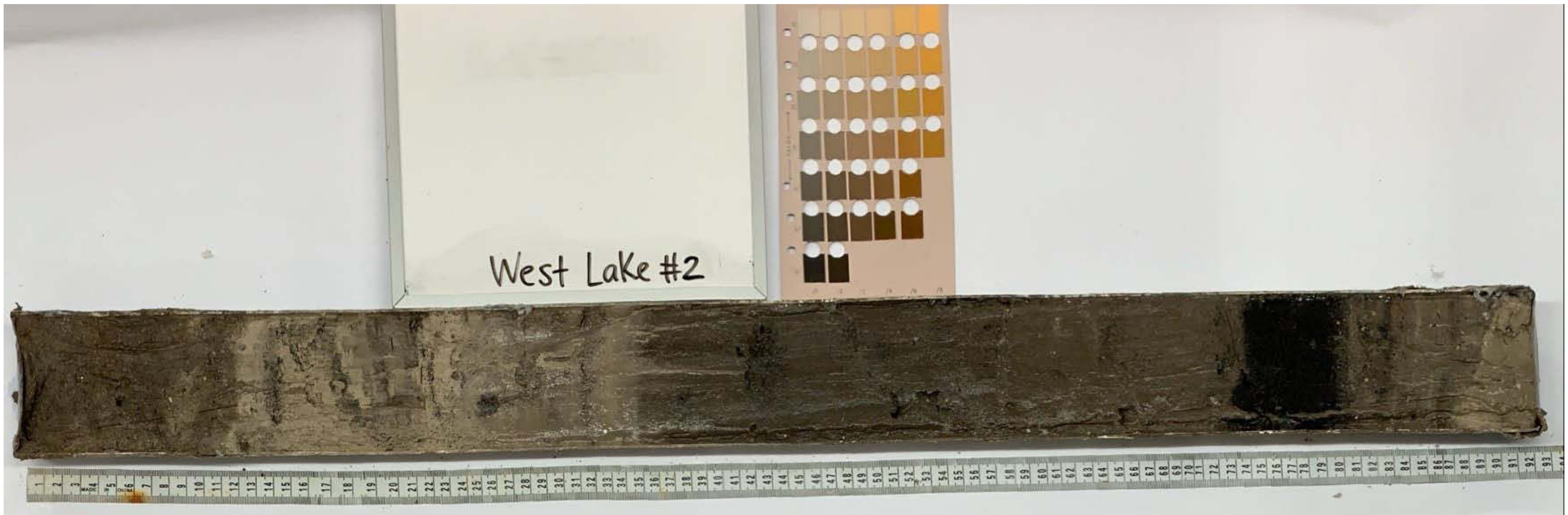
Appendix Table 14. West Lake 1 Elemental Concentrations (μg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	n/d	0.04	0.01	5.77	3.44	5.35	28.4	0.12	1.49	49.8	30.4	0.580	8.12	0.39
10	0.05	0.065	n/d	7.52	4.14	5.47	28.4	0.14	1.72	47.2	25.3	0.47	9.04	0.37
15	0.581	0.089	0.044	8.47	4.98	5.82	27.8	0.16	1.84	38.6	17.9	0.687	8.38	0.32
20	0.833	0.13	0.088	11.0	9.20	8.75	35.9	0.35	2.87	19.2	10.1	1.21	6.22	0.425
25	0.22	0.088	n/d	6.53	4.30	6.39	24.0	0.21	1.60	11.5	5.55	0.502	5.28	0.25
30	0.24	0.050	n/d	3.28	4.76	6.01	18.1	0.28	1.52	4.07	1.95	0.586	4.63	0.25
35	0.34	0.087	0.056	6.40	5.37	7.33	26.0	0.26	1.82	19.4	10.3	0.837	4.21	0.29
40	0.23	0.072	n/d	4.70	5.17	7.46	43.5	0.34	1.78	5.82	3.05	0.454	2.96	0.26
45	0.58	0.28	0.20	16.4	8.30	8.37	55.9	0.37	3.07	30.5	15.6	0.904	10.4	0.45
50	0.789	0.11	0.15	11.9	7.43	6.66	72.60	0.35	2.76	23.3	11.7	1.18	12.5	0.52
55	0.51	0.10	0.21	10.0	6.47	5.18	63.17	0.30	2.28	20.4	9.26	0.49	10.8	0.57
60	0.856	0.045	0.003	7.10	5.32	4.13	70.62	0.29	1.55	12.8	4.10	0.827	10.3	0.567
65	0.34	0.02	n/d	4.87	4.04	3.30	55.4	0.21	1.35	7.80	3.15	0.38	11.7	0.49
70	0.583	0.04	n/d	5.00	4.86	3.39	72.34	0.25	1.31	10.9	2.96	0.28	14.0	0.713
75	1.39	0.04	n/d	3.36	4.09	2.96	70.07	0.28	1.23	6.60	1.63	0.585	12.1	0.593
80	0.27	0.01	n/d	0.642	1.21	0.973	80.13	0.18	0.438	1.07	0.430	0.31	4.85	0.18
85	n/d	0.004	n/d	1.07	1.34	2.80	78.98	0.22	0.649	0.916	0.29	0.19	2.60	0.12
90	n/d	0.01	n/d	1.64	2.04	3.39	71.0	0.25	0.72	4.94	1.53	0.30	3.18	0.18
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.0	0.0	0.0	0.6	1.2	1.0	18.1	0.1	0.4	0.9	0.3	0.2	2.6	0.1
max	1.4	0.3	0.2	16.4	9.2	8.8	80.1	0.4	3.1	49.8	30.4	1.2	14.0	0.7
median	0.3	0.1	0.0	6.1	4.8	5.4	55.6	0.3	1.6	12.2	4.8	0.5	8.3	0.4
mean	0.4	0.1	0.0	6.4	4.8	5.2	51.2	0.3	1.7	17.5	8.6	0.6	7.8	0.4

Appendix Figure 11. Photo of longitudinally split West Lake Core 1 collected July 9-11, 2019.

Appendix Table 15. West Lake 2 Elemental Concentrations (μg/g) by sediment core depth (cm), with minimum (min), maximum (max), median, and mean values. N/a = End of sediment core. N/d = Not detected. Bold values indicate maximum concentrations by element.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.31	0.10	n/d	11.4	4.94	6.80	34.6	0.17	1.98	37.7	21.1	0.502	6.42	0.27
10	0.074	0.070	n/d	7.24	4.08	6.35	26.8	0.18	1.63	28.3	14.0	0.61	5.23	0.29
15	n/d	0.03	n/d	2.04	2.36	5.17	15.2	0.17	1.08	8.48	1.03	0.34	1.68	0.17
20	0.20	0.045	n/d	4.23	4.36	6.24	17.8	0.27	1.65	2.44	6.70	0.31	3.54	0.26
25	0.16	0.074	0.01	4.54	5.45	7.29	22.6	0.29	1.85	7.15	4.02	0.676	2.99	0.25
30	0.21	0.072	n/d	5.01	5.14	7.53	54.8	0.39	2.01	8.96	4.81	0.064	3.25	0.25
35	0.090	0.18	0.060	7.83	5.92	4.57	46.3	0.21	2.24	16.6	8.95	0.624	11.0	0.56
40	0.46	0.21	0.26	13.1	6.50	6.67	70.1	0.33	2.64	21.1	11.7	0.48	12.3	0.60
45	0.55	0.091	0.12	10.2	5.58	5.64	75.3	0.32	2.21	16.0	9.12	0.53	11.2	0.647
50	0.65	0.12	0.11	11.6	7.85	7.21	78.7	0.41	2.88	21.2	11.4	0.49	12.6	0.55
55	0.41	0.1	0.04	8.96	5.12	4.56	66.1	0.30	1.92	16.8	7.89	0.50	10.6	0.53
60	0.726	0.04	n/d	6.51	5.78	4.29	77.2	0.31	1.61	8.65	2.99	0.45	10.5	0.51
65	0.956	0.053	n/d	5.68	5.36	4.10	66.6	0.31	1.59	9.12	3.52	0.39	13.8	0.43
70	0.975	0.1	n/d	4.54	6.15	4.13	66.5	0.29	1.65	10.9	2.43	0.58	11.0	0.56
75	3.6	n/d	n/d	0.59	59.6	11.2	9.38	0.52	16.8	27.7	1.2	7.70	12.9	0.88
80	2.04	0.01	n/d	0.965	2.24	1.94	57.13	0.28	0.975	2.45	0.513	0.675	21.7	0.704
85	0.813	0.03	n/d	2.19	2.78	2.53	70.81	0.22	1.17	7.41	0.927	0.957	8.75	0.46
90	0.04	n/d	n/d	0.14	0.43	0.34	93.77	0.19	0.597	0.41	0.26	0.601	4.62	0.21
95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
105	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
115	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
120	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
125	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
130	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
135	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
145	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
155	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
160	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
165	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
170	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
175	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
180	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
185	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
195	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
min	0.00	0.00	0.00	0.14	0.43	0.34	9.38	0.17	0.60	0.41	0.26	0.06	1.68	0.17
max	3.61	0.21	0.26	13.1	59.6	11.2	93.8	0.52	17.0	37.7	21.1	7.70	22.0	0.88
median	0.4	0.1	0.0	5.3	5.3	5.4	61.6	0.3	1.8	10.0	4.4	0.5	10.6	0.5
mean	0.7	0.1	0.0	5.9	7.8	5.4	52.8	0.3	2.6	14.0	6.3	0.9	9.1	0.5



Appendix Figure 12. Photo of longitudinally split West Lake Core 2 collected July 9-11, 2019.

Appendix Table 16. North Reef Elemental Concentrations (µg/g) of surface sediment samples (5cm). N/d = Not detected. Bold values indicate maximum concentrations by element.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
NR 1	n/d	0.01	n/d	0.9	5.02	4.7	10.1	0.04	0.41	2.76	0.67	0.99	6.89	0.11
NR 2	n/d	0.03	n/d	1.4	6.8	6.81	13.9	0.1	0.72	4.52	1.02	1.84	6.37	0.04
NR 3	0.01	0.04	n/d	1.5	9.12	7.55	15.6	0.04	0.6	3.24	0.65	1.6	8.55	0.08

Appendix Table 17. South Reef Elemental Concentrations (μg/g) of surface sediment samples (5cm). N/d = Not detected. Bold values indicate maximum concentrations by element.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
SR 1	n/d	0.04	n/d	1.3	3.8	5.32	24.1	0.03	0.62	91.1	28.6	1.85	2.41	0.07
SR 2	n/d	0.03	n/d	1.5	4.19	6.35	13.6	0.03	0.75	3.85	0.59	2.07	3.82	0.12
SR 3	n/d	0.04	n/d	1.8	3.91	6.44	14.6	0.05	0.86	6.97	0.51	1.34	3.32	0.08

Appendix Table 18. Dania Cutoff Canal Geo-Accumulation Index for every 5 cm in depth.

cm	DCC1 As	DCC2 As	DCC3 As	DCC1 Mo	DCC2 Mo	DCC3 Mo	DCC1 Sn	DCC2 Sn	DCC3 Sn
5	4	-2	3	3	-2	2	3	-3	-4
10	2	4	3	0	4	2	1	3	-4
15	4	4	5	3	4	6	2	4	-2
20	5	4	2	4	4	3	3	-1	-4
25	5	5	3	4	5	4	3	4	-4
30	5	5	5	3	5	6	2	-2	-2
35	4	5	6	3	5	7	2	4	-1
40	5	5	5	4	5	4	-3	-2	-3
45	4	4	7	3	4	7	2	3	-1
50	2	5	3	2	5	2	2	3	-4
55	3	2	3	1	2	1	1	1	-5
60	3	1	1	1	1	-2	1	1	-4
65	2	2	2	0	2	-3	0	1	-3
70	3	3	2	-1	3	-1	-3	3	-3
75	3	-2	3	0	-2	-2	-7	1	-3
80		-1	3		-1	-3		1	1
85		-2	2		-2	-3		0	-4
90		0	2		0	-3		0	0
95			2			0			2
100			4			4			2

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely, 3-4 Strongly,
2-3 Moderately to Strongly, 1-2 Moderately
0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 19. Park Headquarters Geo-Accumulation Index for every 5 cm in depth.

cm	PHQ1 Mo	PHQ1 As	PHQ2 Mo	PHQ2 As
5	-3	-1	-5	-1
10	1	0	-4	-1
15	4	2	0	-2
20	4	2	4	3
25	5	3	5	3
30	7	5	5	3
35	6	4	5	4
40	4	2	4	2
45	4	3	6	4
50	3	2	3	2
55	4	3	3	2
60	2	1	3	2
65	1	1	3	2
70	1	2	1	1
75	2	2	2	1
80	2	2	3	3
85	2	2	2	2
90	1	2	3	3
95	1	2	2	3
100	1	2	2	2
105	2	3	2	2
110	3	3	3	3
115	3	3	2	3
120	2	3	4	4
125	2	3	3	4
130	2	2	4	3
135	4	3	3	3
140	4	3	4	3
145	3	3	4	3
150	2	3	2	2
155	2	2	3	3
160			3	3
165			3	3
170			0	1
175			0	1
180			0	1
185			0	1
190			1	1

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely, 3-4 Strongly,
2-3 Moderately to Strongly, 1-2 Moderately
0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 20. South Turning Basin Geo-Accumulation Index for every 5 cm in depth.

cm	STB1 Mo	STB 1 As	STB 1 Cu	STB 2 Mo	STB 2 As	STB 2 Cu
5	2	3	2	2	3	2
10	5	5	0	2	3	2
15	3	3	2	2	3	2
20	3	3	2	3	3	0
25	3	3	1	2	2	-5
30	4	4	1	0	1	-1
35	3	4	0	2	2	-5
40	4	3	0	2	3	-4
45	3	3	-1	3	3	-4
50	4	3	-4	3	3	-7
55	4	3	-3			
60	3	3	0			
65	1	3	-3			
70	-5	0	-6			
75	-2	1	-5			

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely, 3-4 Strongly,
2-3 Moderately to Strongly, 1-2 Moderately
0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 21. Park Education Center Geo-Accumulation Index for every 5 cm in depth.

cm	PEC1 Mo	PEC1 As	PEC2 Mo	PEC2 As	PEC3 Mo	PEC3 As
5	-5	-1	1	3	2	3
10	-4	-2	-3	-1	-1	1
15	-2	0	-4	-2	-3	-1
20	-3	-2	-4	-2	-4	-1
25	-1	0	-1	0	-4	-1
30	-1	1	-1	1	-1	1
35	-1	0	-1	0	-4	-1
40	-1	1	-2	0	0	1
45	-2	0	-1	1	-2	0
50	-1	1	0	1	-1	1
55	0	2	0	1	-1	0
60	1	2	-1	1	-1	1
65	0	1	-1	1	0	1
70	0	1	1	2	0	1
75	-1	0	1	2	0	0
80	-1	-1	2	2	0	1
85	0	1	1	2	0	1
90	-2	-1	2	2	1	2
95	1	1	-2	0	1	2
100	2	2	-2	-1	1	2
105	-1	0	-2	-1	2	3
110	1	2	1	1	2	2
115	1	2	1	2	-2	-1
120	2	3	2	2	1	1
125	2	3	2	2	2	2
130	4	4	5	5	-2	-1
135	3	3	4	3	0	1
140	0	2	2	2	2	2
145	0	1	0	2	4	4
150	-2	-1	2	2	0	1
155	-2	-1	-2	-1	-2	-1
160	0	1	-3	-1	3	3
165	-1	0	-2	-1	3	3
170	-1	0	0	1	2	2
175	-2	-1	0	1	2	2
180	-3	-1			2	2
185					2	2
190					3	4
195					2	2
200					-2	-1

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely, 3-4 Strongly,
2-3 Moderately to Strongly, 1-2 Moderately
0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 22. West Lake Geo-Accumulation Index for every 5 cm in depth.

cm	WL1 As	WL2 As
5	2	2
10	2	1
15	2	0
20	1	1
25	1	0
30	1	1
35	1	2
40	0	2
45	2	2
50	2	2
55	2	2
60	2	2
65	2	3
70	3	2
75	2	3
80	1	3
85	0	2
90	0	1

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely, 3-4 Strongly,
2-3 Moderately to Strongly, 1-2 Moderately
0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 23. North and South Reef Geo-Accumulation Index for every 5 cm in depth.

cm	NR1	NR2	NR3	SR1	SR2	SR3
	As	As	As	As	As	As
5	2	2	2	0	1	1

Geo-accumulation Index (GAI)
GAI > 5 extremely Contaminated, 4-5 Strongly to Extremely
3-4 Strongly 2-3 Moderately to Strongly
1-2 Moderately 0-1 Uncontaminated to Moderately, <0 Uncontaminated

Appendix Table 24. Pollution Load Index Calculations (PLI) for port, WL, and RF locations for every 5 cm in depth

cm	DCC 1	DCC 2	DCC 3	PEC 1	PEC 2	PEC 3	PHQ 1	PHQ 2	STB 1	STB 2	WL 1	WL 2
5	1.1	0.0	0.3	0.1	1.4	1.4	0.0	0.1	0.6	0.7	0.2	0.2
10	0.3	1.0	0.4	0.0	0.1	0.3	0.1	0.0	0.8	0.9	0.1	0.1
15	0.6	0.9	0.5	0.1	0.1	0.1	0.3	0.1	0.9	0.9	0.2	0.1
20	0.6	1.2	0.3	0.0	0.1	0.1	0.3	0.4	0.9	0.4	0.2	0.1
25	0.8	1.1	0.3	0.1	0.2	0.1	0.3	0.5	1.0	0.2	0.1	0.1
30	0.4	0.8	0.5	0.1	0.2	0.2	0.6	0.4	0.9	0.2	0.1	0.1
35	0.5	1.0	0.4	0.1	0.1	0.1	0.5	0.5	0.7	0.1	0.2	0.2
40	0.5	0.7	0.3	0.1	0.1	0.2	0.2	0.2	0.6	0.2	0.1	0.3
45	0.3	0.7	0.4	0.1	0.2	0.1	0.2	0.3	0.5	0.2	0.3	0.2
50	0.1	1.2	0.1	0.1	0.2	0.1	0.2	0.2	0.4	0.1	0.3	0.3
55	0.1	0.1	0.0	0.5	0.1	0.1	0.2	0.2	0.3		0.2	0.2
60	0.1	0.1	0.0	0.4	0.1	0.2	0.1	0.1	0.6		0.1	0.1
65	0.1	0.1	0.0	0.3	0.1	0.3	0.1	0.2	0.2		0.1	0.2
70	0.1	0.6	0.0	0.2	0.4	0.2	0.1	0.0	0.0		0.1	0.2
75	0.2	0.0	0.0	0.1	0.5	0.2	0.1	0.0	0.1		0.1	0.2
80		0.1	0.0	0.0	0.5	0.2	0.1	0.1			0.0	0.1
85		0.1	0.0	0.1	0.3	0.2	0.1	0.1			0.0	0.1
90		0.1	0.0	0.0	0.4	0.3	0.1	0.2			0.1	0.0
95			0.1	0.1	0.2	0.2	0.1	0.1				
100			0.2	0.3	0.3	0.3	0.1	0.1				
105				0.1	0.5	0.5	0.2	0.1				
110				0.2	0.2	0.4	0.1	0.2				
115				0.3	0.2	0.1	0.1	0.1				
120				0.2	0.2	0.2	0.1	0.1				
125				0.2	0.3	0.4	0.1	0.1				
130				0.5	0.5	0.0	0.1	0.2				
135				0.2	0.4	0.1	0.4	0.1				
140				0.1	0.3	0.3	0.3	0.2				
145				0.1	0.2	0.5	0.2	0.3				
150				0.0	0.3	0.2	0.2	0.1				
155				0.1	0.0	0.1	0.1	0.2				
160				0.2	0.0	0.3		0.3				
165				0.1	0.0	0.3		0.2				
170				0.2	0.1	0.2		0.1				
175				0.1	0.1	0.2		0.0				
180				0.1		0.3		0.0				
185						0.3		0.1				
190						0.5		0.1				
195						0.2						
200						0.1						
cm				NR 1	NR 2	NR 3	SR 1	SR 2	SR 3			
5				0.04	0.07	0.06	0.1	0.06	0.06			

Pollution Load Index   >1 Polluted   <1 No Contamination

Appendix Table 25. Potential Ecological Risk Index Calculations (E_{RI}) – port, WL, and RF locations for every 5 cm in depth

cm	DCC 1	DCC 2	DCC 3	PEC 1	PEC 2	PEC 3	PHQ 1	PHQ 2	STB 1	STB 2	WL 1	WL 2
5	364	10	160	21	441	332	12	12	228	220	75	83
10	125	449	204	15	34	54	34	11	491	246	89	63
15	346	406	360	35	15	21	111	12	284	243	90	23
20	527	543	147	17	19	18	119	150	283	0	89	41
25	590	439	176	39	41	20	179	319	278	75	66	46
30	417	642	392	39	48	50	562	292	362	54	48	47
35	293	466	772	37	36	27	339	398	272	98	60	133
40	487	669	386	50	34	46	94	128	207	98	45	154
45	205	556	1502	30	51	27	123	242	142	112	165	109
50	93	1006	128	48	55	36	89	125	167	108	125	127
55	94	127	113	203	40	34	115	129	129		108	93
60	97	89	43	195	36	43	45	85	208		86	85
65	85	119	55	116	42	58	43	114	113		88	112
70	136	446	61	117	131	51	71	41	22		110	93
75	107	55	93	45	185	38	91	39	38		94	98
80		72	90	17	172	43	107	102			36	149
85		96	71	32	146	46	113	96			20	70
90		96	83	10	197	67	100	147			25	30
95			86	53	41	67	77	95				
100			180	122	19	93	60	80				
105				28	14	183	151	77				
110				67	51	142	114	190				
115				108	101	26	164	116				
120				125	76	79	140	214				
125				118	100	123	108	221				
130				501	492	15	67	176				
135				140	182	36	117	182				
140				60	79	108	171	146				
145				35	68	240	131	156				
150				15	111	53	122	69				
155				13	12	13	55	118				
160				42	7	154		153				
165				33	14	136		95				
170				25	31	106		36				
175				19	41	81		36				
180				15		100		28				
185						99		39				
190						287		31				
195						63						
200						11						
cm				NR 1	NR 2	NR 3	SR 1	SR 2	SR 3			
5				50	53	70	62	36	36			

Potential Ecological Risk (E_{ri})

E_{ri} > 320 significantly high — 160 < E_{ri} < 320 high — 80 < E_{ri} < 160 considerable

40 < E_{ri} < 80 moderate — E_{ri} < 40 low

Appendix Table 26. Dania Cutoff Canal 1 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	16.1	0.25	0	6.35	32.4	34.9	76.2	0.62	11.3	102.0	174.5	52.2	36.4	2.96
10	2.97	0.051	0	3.01	7.72	7.41	18.4	0.16	2.26	73.91	150.8	14.8	11.4	0.659
15	20.1	0.17	0	2.11	24.8	25.7	48.2	0.47	8.72	9.30	13.40	45.2	42.9	2.30
20	36.3	0.26	0	2.00	31.3	22.8	52.4	0.56	8.99	13.1	4.36	54.3	66.2	2.60
25	36.2	0.30	0	2.36	37.4	27.8	62.2	0.62	10.1	17.3	20.3	54.5	73.2	2.59
30	24.9	0.19	0	1.52	23.3	15.3	43.4	0.47	5.98	4.07	3.51	32.7	53.2	1.70
35	18.7	0.15	0	2.72	24.5	14.3	42.3	0.49	5.14	12.5	9.4	24.4	36.3	1.39
40	45.9	0.23	0	1.71	38.9	15.4	70.5	0.76	7.29	10.0	23.4	1.03	61.2	2.01
45	17.9	0.080	0	1.07	15.0	6.25	63.7	0.51	3.11	5.37	3.70	32.1	26.7	1.14
50	7.06	0.03	0	0.23	5.10	1.96	129.6	0.34	1.23	1.48	0.532	25.3	12.6	0.494
55	3.72	0.01	0	0.060	1.25	0.824	119.1	0.33	0.760	1.01	0.22	16.1	13.5	0.434
60	4.62	0.01	0	0.089	2.31	0.788	147.1	0.29	0.830	1.01	0.381	16.2	14.0	0.458
65	1.91	0.01	0	0.15	0.950	0.701	144.0	0.26	0.523	0.807	0.288	6.13	12.3	0.319
70	0.88	0.01	0	0.35	1.13	0.85	162.5	0.35	0.89	75.4	55.4	1.28	17.9	0.26
75	2.93	0.00	0	8.21	5.92	13.6	79.65	1.81	3.57	14.6	10.3	0.05	15.0	0.681

Values above TEL range; Values above PEL range

Appendix Table 27. Dania Cutoff Canal 2 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.48	0.01	0	1.43	2.00	2.01	5.14	0.04	0.47	5.17	3.90	0.730	0.803	0.05
10	45.9	0.46	0	4.00	41.5	56.8	47.0	0.92	18.6	10.3	11.9	90.2	44.3	4.55
15	44.1	0.39	0	3.62	47.2	51.8	45.2	0.81	16.8	7.82	10.4	140	41.3	4.22
20	44.5	0.43	0	4.27	73.9	46.4	75.0	0.88	15.2	28.9	40.7	1.37	56.2	3.56
25	58.3	0.38	0	3.88	66.7	53.5	44.7	0.92	19.5	17.5	11.5	131	46.5	4.29
30	62.9	0.48	0	3.97	53.7	50.3	60.6	0.85	16.7	10.1	10.2	2.0	72.6	4.79
35	52.4	0.34	0	4.15	42.4	37.7	73.7	0.83	14.0	14.3	12.7	106	52.8	2.88
40	60.8	0.40	0	3.97	46.0	34.1	63.1	0.87	13.1	19.8	10.9	1.9	80.6	2.90
45	26.8	0.28	0	2.63	34.7	21.8	50.5	0.69	9.39	13.8	8.94	59.2	69.6	2.42
50	88.9	0.51	0	1.5	100	23.3	63.3	1.25	11.0	241.9	5.74	81.9	126	2.92
55	8.41	0.03	0	0.091	4.02	1.19	103.2	0.33	1.05	0.979	0.36	18.4	17.6	0.57
60	5.50	0.01	0	0.10	2.64	0.78	121.1	0.22	0.775	1.10	0.28	20.9	12.8	0.35
65	6.98	0.03	0	0.27	3.63	2.60	138.0	0.30	1.64	1.42	0.613	23.3	16.3	0.673
70	19.5	0.24	0	2.50	31.4	24.1	75.8	0.56	9.23	5.50	4.72	69.6	55.0	2.14
75	0.570	0.01	0	0.036	0.619	0.26	110.8	0.12	0.463	1.67	0.21	12.9	7.79	0.33
80	1.37	0.01	0	0.084	1.60	0.502	119.7	0.30	0.542	0.83	0.24	17.9	10.3	0.29
85	0.777	0.00	0	0.20	1.25	0.756	99.88	0.18	0.458	0.23	0.1	7.18	14.3	0.399
90	1.59	0.01	0	1.38	3.06	3.77	143.0	0.706	1.41	1.36	0.460	7.93	13.8	0.506

Values above TEL range; Values above PEL range

Appendix Table 28. Dania Cutoff Canal 3 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.30	0.10	0	5.28	15.5	11.1	14.0	0.24	4.18	41.5	26.1	0.45	18.1	0.849
10	11.8	0.18	0	4.77	22.7	9.63	23.9	0.52	5.00	40.6	27.7	0.68	21.2	0.843
15	137	0.02	0	2.82	53.1	26.1	10.9	0.31	6.27	54.5	7.61	1.5	52.2	2.812
20	18.2	0.23	0	2.45	23.1	7.59	28.88	0.752	4.64	24.0	11.2	0.44	10.6	0.640
25	38.9	0.08	0	2.88	14.8	5.26	19.7	0.32	2.39	15.2	12.3	0.50	22.0	0.599
30	129	0.15	0	2.16	31.4	6.27	57.0	0.94	3.72	19.6	11.5	1.80	51.1	1.58
35	244.9	0.03	0	1.7	37.7	16.3	42.2	0.48	4.60	4.92	4.75	3.03	114	2.85
40	26.1	0.1	0	0.31	3.87	2.53	203.6	1.06	1.71	387.1	0.80	1.03	54.3	1.15
45	384.5	0.04	0	0.59	17.5	7.12	67.7	0.87	3.60	2.3	3.89	4.18	223	3.94
50	8.17	0.03	0	0.080	1.55	0.692	113.0	0.39	0.967	1.32	0.22	0.597	17.8	0.43
55	5.67	0.01	0	0.055	0.570	0.427	86.76	0.23	0.504	0.11	0.20	0.31	16.2	0.405
60	0.639	0.00	0	0.02	0.16	0.16	110.4	0.19	0.30	0.31	0.063	0.495	6.33	0.31
65	0.34	0.0	0	0.02	0.26	0.22	102.5	0.19	0.42	0.36	0.13	0.964	8.12	0.31
70	1.51	0.01	0	0.02	0.23	0.23	133.7	0.28	0.60	0.26	0.08	0.867	8.70	0.27
75	0.48	0.0	0	0.1	0.23	0.22	127.5	0.47	0.51	0.43	0.0	1.18	14.0	0.24
80	0.22	0.002	0	0.03	0.33	0.23	93.03	0.32	0.599	0.46	0.13	13.2	13.3	0.424
85	0.25	0.01	0	0.11	0.39	0.42	156.2	0.31	0.670	2.22	0.32	0.720	10.1	0.37
90	0.24	0.0	0	0.051	0.35	0.27	108.8	0.477	0.465	0.21	0.083	10.2	12.3	0.22
95	2.10	0.01	0	0.077	2.55	0.634	128.1	0.24	0.46	0.547	0.29	25.2	12.5	0.34
100	29.6	0.03	0	0.662	4.08	2.08	160.6	0.55	1.18	1.52	0.58	34.4	25.6	0.58

Values above TEL range; Values above PEL range

Appendix Table 29. Park Education Center 1 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.065	0.03	0.0	3.22	3.14	5.30	11.2	0.14	1.25	17.3	12.5	0.11	1.34	0.13
10	0.12	0.028	0.0	1.60	2.34	4.22	5.83	0.10	0.696	8.60	5.00	0.046	0.641	0.06
15	0.743	0.052	0.0	3.61	6.11	6.29	7.89	0.15	1.94	25.7	15.7	0.13	2.01	0.15
20	0.21	0.032	0.0	1.29	2.82	3.55	5.56	0.10	0.725	10.6	3.78	0.035	0.775	0.06
25	1.04	0.048	0.0	3.87	10.1	7.93	9.69	0.22	2.84	17.2	13.2	0.12	2.81	0.17
30	1.18	0.032	0.0	1.92	9.81	9.74	10.4	0.288	2.38	6.88	5.05	0.063	3.93	0.269
35	1.20	0.046	0.0	2.06	11.5	16.6	17.2	0.447	3.00	2.80	1.89	0.00	2.94	0.31
40	1.51	0.052	0.01	4.16	10.5	16.0	22.0	0.532	3.60	5.19	3.60	0.051	4.54	0.30
45	0.444	0.03	0.0	1.50	7.00	12.1	11.8	0.33	2.06	3.65	1.12	0.00	2.97	0.34
50	0.965	0.051	0.0	2.76	10.1	13.2	20.3	0.532	3.14	9.83	2.29	0.01	4.42	0.33
55	3.14	0.34	0.36	20.1	55.0	14.4	30.4	0.747	16.4	33.3	28.1	0.40	12.1	0.61
60	3.86	0.33	0.25	13.7	34.2	11.3	23.6	0.54	10.37	29.9	22.7	0.11	12.1	0.646
65	2.85	0.22	0.29	10.3	16.0	6.70	14.5	0.28	4.53	19.0	15.2	0.22	6.16	0.38
70	2.79	0.24	0.16	8.50	11.6	6.13	15.8	0.23	2.96	16.2	10.5	0.19	5.62	0.27
75	0.886	0.09	0.02	3.39	3.47	2.43	7.36	0.093	1.15	6.66	3.56	0.036	2.10	0.09
80	0.808	0.03	0.0	1.21	1.28	1.30	4.79	0.055	0.399	3.10	1.05	0.02	1.13	0.00
85	1.98	0.03	0.01	2.40	4.50	2.88	11.3	0.13	0.897	6.22	3.23	0.072	3.24	0.16
90	0.484	0.01	0.072	0.971	0.654	1.23	5.34	0.048	0.567	4.07	0.879	0.0059	0.850	0.01
95	5.14	0.04	0.0	4.46	7.10	4.98	22.2	0.27	1.63	8.37	6.58	0.28	5.76	0.28
100	9.19	0.13	0.0	9.01	24.0	12.0	34.2	0.50	5.05	21.3	15.5	0.35	11.1	0.76
105	1.32	0.02	0.0	2.61	3.72	2.96	12.4	0.14	1.01	4.30	3.85	0.045	2.80	0.15
110	3.93	0.06	0.0	5.38	10.3	5.84	20.5	0.23	3.12	13.4	3.89	0.37	6.99	0.48
115	4.37	0.088	0.736	3.74	15.0	9.44	35.8	0.37	3.68	10.5	4.13	0.19	11.6	0.817
120	8.14	0.1	0.0	3.52	15.9	7.53	26.8	0.36	2.79	8.59	3.11	0.18	15.4	0.59
125	8.92	0.079	0.0	5.66	15.2	8.45	32.2	0.31	3.27	9.06	3.78	0.055	13.5	0.767
130	43.8	0.92	0.0	3.99	50.7	21.0	20.4	0.67	11.3	6.79	4.97	0.00	32.1	2.26
135	14.1	0.11	0.0	3.98	15.3	6.11	23.3	0.33	2.81	5.26	2.84	0.17	15.8	0.666
140	2.91	0.03	0.0	2.29	7.20	4.16	18.1	0.26	1.51	4.73	1.65	0.12	7.32	0.32
145	2.72	0.03	0.003	1.81	5.24	3.42	17.4	0.14	0.990	3.58	1.31	0.086	3.82	0.23
150	0.789	0.01	0.005	1.28	3.67	2.75	6.89	0.16	0.604	1.55	0.729	0.0038	1.49	0.15
155	0.772	0.01	0.055	3.39	8.76	7.52	9.71	0.517	1.67	1.06	2.1	0.10	0.880	0.35
160	2.28	0.044	0.12	2.10	33.4	7.64	30.5	0.752	2.45	2.81	2.03	0.38	4.01	0.41
165	1.50	0.04	0.048	1.89	22.3	5.64	47.1	0.882	2.47	2.60	3.66	0.14	2.87	0.29
170	1.21	0.03	0.0	1.78	27.7	5.85	41.1	0.67	2.76	11.3	2.92	12.2	2.05	0.14
175	0.43	0.03	0.0	1.39	9.92	4.45	27.3	0.42	1.63	1.24	1.55	0.56	1.11	0.12
180	0.34	0.02	0.0	1.49	8.77	4.86	28.5	0.39	1.77	2.35	1.34	0.17	0.937	0.10

Values above TEL range; Values above PEL range

Appendix Table 30. Park Education Center 2 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	4.94	0.77	0.24	73.8	59.0	46.6	73.3	2.22	29.3	415.6	214.9	3.27	18.9	1.35
10	0.23	0.053	0.0	4.82	5.16	7.78	14.9	0.25	2.20	25.7	22.2	0.572	1.56	0.16
15	0.11	0.03	0.0	1.84	2.24	4.30	6.63	0.11	0.990	12.3	4.76	1.12	0.61	0.10
20	0.10	0.04	0.0	1.37	2.41	3.39	6.45	0.13	0.800	6.23	2.96	0.687	0.753	0.09
25	1.08	0.1	0.0	3.64	13.8	9.60	11.6	0.32	3.65	9.81	7.22	1.08	2.61	0.22
30	1.37	0.074	0.0	2.45	12.0	12.9	18.9	0.39	3.34	7.55	5.81	0.46	3.21	0.20
35	1.37	0.1	0.0	2.42	12.0	19.7	17.0	0.53	3.40	2.79	1.80	0.30	2.45	0.23
40	0.69	0.1	0.0	2.17	11.7	18.9	16.7	0.43	3.28	3.35	1.55	0.54	2.18	0.13
45	1.50	0.053	0.0	3.47	10.8	17.6	24.6	0.579	3.41	3.88	2.38	0.29	4.64	0.357
50	2.06	0.1	0.0	3.67	11.5	18.9	23.6	0.59	4.19	6.11	3.42	0.54	4.21	0.14
55	1.68	0.046	0.0	2.63	12.3	17.9	18.6	0.543	3.20	2.81	1.83	0.33	3.43	0.31
60	1.05	0.03	0.0	2.06	7.8	11.8	14.0	0.367	2.56	4.33	1.62	0.22	3.59	0.35
65	0.98	0.054	0.01	2.62	10.8	16.4	18.3	0.543	3.14	3.05	2.06	0.26	3.29	0.30
70	3.29	0.20	0.26	9.56	34.2	13.4	25.3	0.589	10.6	16.6	13.8	1.02	8.94	0.613
75	5.50	0.33	0.33	14.0	44.5	11.4	21.6	0.586	12.1	25.0	24.1	1.10	10.4	0.616
80	7.27	0.33	0.632	18.0	31.4	10.3	22.5	0.461	10.1	28.2	25.8	1.10	8.85	0.623
85	4.09	0.28	0.20	10.1	15.2	7.17	16.4	0.28	3.77	18.5	15.5	0.668	8.08	0.530
90	8.71	0.44	0.488	15.6	15.4	9.15	26.1	0.36	3.72	25.6	16.0	0.881	8.24	0.602
95	0.55	0.069	0.0	17.6	1.01	1.84	12.7	0.10	0.61	7.38	2.64	1.12	2.19	0.12
100	0.51	0.04	0.0	1.79	1.23	1.39	6.57	0.06	0.42	3.97	1.40	0.702	1.09	0.03
105	0.60	0.02	0.0	1.31	0.94	1.39	5.73	0.058	0.42	4.26	1.22	1.12	0.804	0.05
110	4.17	0.041	0.01	5.37	14.7	5.71	31.4	0.28	1.70	8.98	9.39	0.429	5.10	0.28
115	6.33	0.071	0.02	3.25	81.06	7.43	30.7	0.25	1.94	14.6	3.65	1.19	11.5	0.525
120	6.64	0.062	0.0	2.88	63.77	7.36	28.1	0.23	1.97	6.49	3.45	0.782	8.09	0.512
125	8.30	0.078	0.0	7.80	49.4	10.1	41.9	0.45	3.25	9.83	6.89	1.17	10.6	0.72
130	89.8	0.24	0.0	1.6	106	13.1	53.4	2.06	4.93	4.04	2.41	3.19	62.4	1.6
135	30.2	0.10	0.1	3.46	176.2	16.8	48.9	0.52	5.13	6.6	3.05	2.44	22.0	1.39
140	6.99	0.065	0.0	6.57	109.9	10.1	45.6	0.37	2.82	7.37	4.04	0.824	8.27	0.548
145	3.13	0.1	0.0	7.99	15.7	7.87	32.3	0.35	2.45	10.0	5.24	0.768	6.75	0.44
150	8.70	0.084	0.0	4.25	43.6	10.7	30.9	0.37	2.96	6.13	4.09	0.802	12.2	0.732
155	0.48	0.01	0.0	0.27	0.927	0.991	2.72	0.03	0.39	0.608	0.054	0.548	1.25	0.056
160	0.24	0.005	0.0	0.24	0.704	0.669	1.96	0.03	0.23	0.709	0.004	0.495	0.799	0.0
165	0.77	0.01	0.0	0.436	1.80	1.34	4.23	0.056	0.443	0.818	0.25	0.13	1.45	0.049
170	2.65	0.03	0.03	1.03	9.88	2.93	18.1	0.33	1.16	1.20	1.10	0.28	3.35	0.10
175	1.74	0.04	0.0	1.67	15.9	5.44	27.4	0.45	1.92	2.91	2.34	0.0	3.86	0.31

Values above TEL range; Values above PEL range

Appendix Table 31. Park Education Center 3 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	10.1	0.39	0.25	35.9	100.4	41.1	98.08	1.23	22.2	225.3	210.2	14.6	22.2	1.25
10	1.50	0.077	0.0	4.24	20.2	13.4	18.8	0.40	5.00	14.6	10.5	11.7	3.75	0.24
15	0.26	0.04	0.0	1.65	5.90	5.41	8.06	0.18	1.67	5.61	3.16	9.83	1.23	0.050
20	0.14	0.03	0.0	1.73	4.25	4.17	5.84	0.13	1.13	7.11	4.61	15.6	1.00	0.00
25	0.12	0.04	0.0	1.69	4.34	4.31	5.75	0.12	1.16	7.50	4.81	11.7	1.04	0.045
30	1.28	0.068	0.0	3.75	15.3	11.4	13.3	0.35	3.99	15.7	11.3	8.68	3.56	0.28
35	0.19	0.03	0.0	1.59	4.59	4.44	6.47	0.12	1.31	602.8	4.36	11.0	0.979	0.581
40	2.08	0.050	0.0	2.31	11.7	13.2	15.3	0.450	2.92	4.05	3.11	4.06	4.12	0.28
45	0.588	0.033	0.0	1.00	6.13	11.0	11.2	0.296	1.74	10.8	0.792	2.74	2.25	0.303
50	1.03	0.03	0.0	1.57	9.66	13.8	13.6	0.408	2.36	1.60	1.43	2.23	3.78	0.502
55	1.30	0.048	0.0	2.16	10.4	14.4	16.1	0.394	2.60	1.60	1.42	2.71	2.49	0.307
60	1.27	0.046	0.0	3.01	10.8	19.4	25.5	0.551	3.36	3.05	2.01	4.34	3.78	0.34
65	1.83	0.075	0.11	6.91	13.0	19.9	27.7	0.624	4.60	14.3	6.95	4.00	4.33	0.478
70	1.90	0.068	0.0	3.08	10.9	17.1	22.3	0.574	3.45	3.01	2.74	3.11	3.97	0.346
75	2.01	0.05	0.0	2.35	10.5	14.5	16.8	0.50	3.02	2.79	1.94	9.88	3.09	0.23
80	1.77	0.058	0.0	3.28	12.1	18.9	18.7	0.551	3.24	3.18	1.97	3.80	3.32	0.32
85	2.42	0.052	0.0	3.09	11.5	16.2	20.5	0.560	3.35	2.89	2.34	4.31	4.01	0.39
90	3.76	0.063	0.0	3.64	17.2	19.7	26.1	0.899	5.37	3.49	2.85	7.37	6.55	0.588
95	4.24	0.1	0.0	3.54	15.1	17.1	26.7	0.908	4.02	4.20	2.54	8.89	6.60	0.400
100	4.51	0.11	0.11	5.11	28.6	13.5	21.2	0.567	6.88	5.69	6.29	6.73	8.32	0.473
105	7.17	0.25	0.29	13.2	38.79	12.0	21.3	0.527	10.1	23.1	22.4	5.96	14.4	0.757
110	6.65	0.29	0.20	10.1	16.6	7.55	15.4	0.29	4.10	19.2	13.7	5.72	7.14	0.470
115	0.750	0.05	0.0	2.15	2.32	1.77	6.02	0.058	0.654	3.82	2.18	8.22	1.50	0.062
120	4.22	0.12	0.14	4.21	7.53	4.07	12.0	0.18	1.53	10.4	4.45	6.33	5.88	0.26
125	8.33	0.13	0.47	6.73	16.3	7.50	26.1	0.33	3.01	22.6	8.82	6.17	12.0	0.50
130	0.79	0.02	0.0	3.14	1.17	1.65	5.73	0.057	0.45	5.60	1.29	7.34	1.21	0.003
135	2.04	0.039	0.0	2.70	10.7	3.72	15.3	0.14	1.21	4.31	2.65	6.51	3.34	0.25
140	10.2	0.10	0.0	5.49	37.4	9.90	28.8	0.38	3.06	8.02	5.10	10.5	10.9	0.923
145	30.1	0.16	0.0	4.55	80.73	16.1	59.2	0.52	4.68	9.23	4.64	15.6	27.8	1.27
150	2.37	0.05	0.04	6.57	9.14	5.77	24.2	0.30	2.14	8.06	4.01	0.574	5.29	0.39
155	0.46	0.01	0.0	1.21	1.67	1.73	7.63	0.1	0.50	1.49	0.67	0.857	1.41	0.00
160	15.6	0.1	0.0	1.91	38.2	14.5	17.0	2.06	17.0	4.95	5.02	1.72	18.9	1.1
165	13.8	0.1	0.0	1.87	45.7	15.7	11.2	3.52	17.0	1.50	5.03	1.2	15.4	1.23
170	7.84	0.10	0.0	3.07	41.6	15.8	10.6	2.41	13.5	1.89	4.76	0.12	10.5	1.16
175	6.81	0.08	0.01	3.24	39.7	13.3	8.60	1.45	9.57	3.03	4.05	0.23	7.43	1.10
180	8.09	0.072	0.0	3.19	46.2	16.1	10.1	2.57	13.3	4.26	4.18	0.10	10.7	1.13
185	6.99	0.089	0.0	3.84	41.7	16.1	10.1	2.13	14.7	2.60	4.07	0.22	9.72	0.940
190	22.1	0.22	0.0	4.78	124.3	32.7	15.2	6.84	20.0	1.91	3.69	0.50	31.5	1.67
195	8.32	0.05	0.0	2.12	24.2	6.39	21.0	1.1	3.69	1.76	1.92	0.26	6.81	0.35
200	0.43	0.01	0.0	1.51	4.94	3.42	16.6	0.35	1.28	2.02	1.1	0.49	1.1	0.1

Values above TEL range; Values above PEL range

Appendix Table 32. Park Headquarters 1 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.39	0.02	0.0	1.50	1.55	2.53	7.86	0.051	0.36	6.65	2.77	0.734	0.958	0.01
10	3.42	0.04	0.0	1.46	4.34	4.09	10.6	0.13	1.23	75.47	2.97	0.820	2.86	0.24
15	40.4	0.1	0.0	2.2	36.1	13.3	11.4	0.2	4.73	16.5	6.96	3.15	11.3	0.95
20	45.0	0.1	0.0	1.5	32.5	12.1	8.42	0.2	4.38	5.97	2.93	3.89	11.4	1.4
25	63.1	0.1	0.0	1.2	48.3	19.5	5.53	0.19	5.51	4.01	2.29	2.66	21.8	1.3
30	269.5	0.18	0.0	2.43	67.2	32.0	14.0	0.33	8.94	6.31	7.50	2.77	75.0	3.69
35	133	0.20	0.0	3.73	47.2	28.3	16.9	0.34	7.70	8.44	7.95	2.29	40.6	3.10
40	37.0	0.1	0.0	1.14	18.6	13.0	8.12	0.13	3.93	5.55	2.89	1.18	10.8	1.17
45	43.2	0.1	0.0	1.51	24.4	15.9	8.34	0.16	3.88	4.27	3.39	1.59	15.1	1.51
50	20.6	0.02	0.0	0.861	17.2	8.72	5.88	0.21	2.82	7.99	1.90	1.01	11.9	0.79
55	28.2	0.03	0.0	0.937	25.2	10.6	5.93	0.11	2.62	1.90	2.42	1.18	15.4	0.89
60	7.05	0.01	0.0	0.40	5.82	4.31	2.71	0.04	1.02	0.895	0.741	0.600	6.04	0.36
65	5.34	0.02	0.0	0.40	4.56	3.91	2.35	0.03	0.906	2.86	0.945	0.574	5.48	0.26
70	5.75	0.057	0.0	0.834	8.40	6.25	7.86	0.10	1.92	1.65	1.37	0.52	7.85	0.37
75	8.38	0.070	0.0	0.685	11.3	8.77	7.83	0.13	2.80	1.33	1.22	0.53	10.1	0.618
80	7.10	0.11	0.0	0.818	9.17	8.47	9.27	0.15	2.66	39.3	1.48	0.19	10.9	0.487
85	7.92	0.11	0.0	0.772	10.5	8.65	8.72	0.13	2.71	0.852	1.11	0.39	11.5	0.515
90	5.17	0.067	0.0	0.671	7.73	6.60	9.85	0.10	1.76	1.74	0.791	0.458	11.6	0.38
95	4.79	0.046	0.0	0.447	4.96	4.69	6.09	0.072	1.10	0.741	0.404	0.379	9.29	0.27
100	3.73	0.04	0.0	0.805	4.25	3.68	4.58	0.068	1.03	3.84	0.731	0.538	6.98	0.14
105	10.8	0.11	0.0	1.08	14.9	11.0	12.9	0.16	2.56	1.72	1.07	1.07	17.5	0.50
110	15.6	0.053	0.0	0.454	10.9	5.96	7.24	0.11	1.54	1.41	0.590	0.431	14.5	0.35
115	13.0	0.11	0.0	0.719	18.0	9.47	9.69	0.16	2.94	1.28	0.891	0.466	19.1	0.605
120	9.89	0.052	0.0	0.512	14.5	6.55	8.21	0.11	1.47	1.34	0.494	0.544	18.4	0.442
125	9.10	0.052	0.0	0.609	7.49	5.05	7.72	0.12	1.33	0.815	0.415	0.384	13.7	0.26
130	6.97	0.04	0.0	0.42	10.0	4.99	7.22	0.091	1.17	1.20	0.26	0.724	8.26	0.34
135	28.0	0.0	0.0	0.41	47.3	20.6	16.9	0.71	4.92	241	0.79	7.21	16.6	1.9
140	48.7	0.1	0.0	0.32	55.7	19.3	17.6	0.60	4.57	1.7	0.86	3.35	22.4	1.5
145	19.4	0.03	0.0	0.1	25.7	11.1	37.2	1.0	3.23	1.91	0.67	2.68	18.1	1.0
150	11.7	0.02	0.0	0.15	13.0	7.34	30.2	7.40	11.5	7.31	0.63	2.38	16.9	1.05
155	6.92	0.0	0.0	0.20	5.95	3.38	30.0	3.27	12.1	2.35	0.19	2.58	7.58	0.43

Values above TEL range; Values above PEL range

Appendix Table 33. Park Headquarters 2 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.081	0.01	0.0	1.87	2.12	2.27	13.1	0.082	0.66	8.22	3.71	0.960	0.933	0.05
10	0.17	0.01	0.0	1.93	2.09	1.93	10.5	0.1	0.53	7.48	4.38	1.05	1.05	0.01
15	0.0	0.01	0.0	1.61	1.85	2.75	9.67	0.1	0.50	7.59	3.46	1.37	0.77	0.0
20	33.4	0.16	0.0	4.21	34.7	21.5	18.8	0.37	8.77	9.27	5.28	1.96	14.4	2.07
25	65.9	0.49	0.0	2.97	44.2	20.4	21.7	0.52	11.8	7.02	5.11	1.67	24.4	2.09
30	54.1	0.55	0.0	2.19	31.3	12.2	17.4	0.37	5.41	6.85	4.01	1.25	17.8	1.27
35	96.3	0.70	0.0	2.69	70.8	42.8	14.9	0.59	18.6	3.14	3.01	2.0	26.3	2.63
40	35.2	0.17	0.0	0.793	15.7	9.07	5.54	0.14	3.44	0.605	1.68	0.783	11.1	0.863
45	119	0.1	0.0	1.0	30.7	13.7	7.61	0.22	4.00	4.44	2.54	1.73	32.5	1.60
50	25.0	0.15	0.0	0.694	16.2	9.93	6.18	0.15	3.86	1.48	1.92	0.694	11.4	0.882
55	21.5	0.17	0.0	0.630	22.9	9.84	6.43	0.21	4.42	1.33	1.88	0.729	11.0	0.831
60	15.4	0.065	0.0	0.539	15.7	6.92	3.78	0.094	2.23	0.866	1.47	0.572	9.53	0.631
65	14.5	0.14	0.0	0.745	19.5	10.4	6.15	0.15	4.08	3.59	1.95	0.658	10.6	0.842
70	5.50	0.01	0.0	0.35	5.60	3.67	1.61	0.02	0.72	0.54	0.56	0.869	5.60	0.32
75	6.92	0.0	0.0	0.51	3.88	4.39	2.26	0.03	0.734	0.71	0.63	0.67	5.58	0.32
80	13.1	0.02	0.0	1.08	8.77	10.7	5.42	0.1	1.44	1.20	1.53	1.02	14.2	0.81
85	10.6	0.03	0.0	1.03	8.58	10.5	3.86	0.11	1.59	2.97	1.96	0.81	12.7	0.66
90	16.9	0.04	0.0	1.37	15.6	17.9	9.57	0.14	2.95	5.69	2.97	0.62	20.0	0.933
95	8.98	0.01	0.0	0.815	6.27	8.59	3.38	0.059	1.11	2.49	1.67	0.27	13.5	0.555
100	6.95	0.004	0.0	0.652	5.07	6.68	2.28	0.044	0.804	0.28	1.09	0.22	11.6	0.373
105	7.27	0.01	0.0	0.596	6.25	6.66	2.54	0.05	0.698	0.935	0.707	0.567	11.1	0.35
110	13.2	0.19	0.0	0.990	10.9	10.2	22.8	0.29	4.80	2.15	1.14	0.867	19.5	0.51
115	9.38	0.070	0.0	0.734	7.17	7.60	11.7	0.11	1.96	2.05	0.745	0.874	13.9	0.37
120	37.5	0.04	0.0	1.05	18.6	11.4	4.94	0.087	1.87	0.816	1.46	0.44	30.1	0.808
125	25.1	0.054	0.0	0.810	25.6	11.4	5.14	0.10	1.95	2.27	1.29	0.34	30.4	0.887
130	27.0	0.075	0.0	0.889	15.2	12.4	8.25	0.15	2.33	1.31	1.17	0.59	22.6	0.613
135	21.3	0.1	0.0	1.17	10.4	9.58	7.77	0.13	1.85	0.919	0.70	0.72	23.9	0.43
140	40.3	0.03	0.0	0.33	52.0	21.7	34.1	0.83	4.55	0.40	0.96	2.62	20.1	1.61
145	33.3	0.05	0.0	0.45	38.9	19.4	21.8	0.92	6.20	16.2	1.2	3.40	20.6	1.86
150	7.35	0.04	0.0	0.36	10.2	6.18	7.00	0.40	2.65	2.69	0.67	1.39	8.27	0.68
155	23.5	0.04	0.0	0.24	24.9	14.0	14.0	1.8	6.22	4.09	1.0	4.71	15.6	2.00
160	20.2	0.1	0.0	0.29	15.8	23.8	27.3	2.26	8.23	1.4	1.65	3.23	19.5	1.85
165	21.2	0.02	0.0	0.1	12.8	9.79	16.7	1.4	10.5	0.32	1.2	4.59	12.8	1.7
170	3.06	0.003	0.0	0.03	2.38	2.22	43.5	0.32	3.29	0.31	0.31	1.28	5.01	0.52
175	1.78	0.00002	0.0	0.04	1.61	1.45	33.1	0.22	2.57	0.16	0.10	0.853	5.22	0.37
180	1.63	0.001	0.0	0.1	1.95	1.68	34.0	0.32	3.65	0.15	0.31	1.01	3.96	0.27
185	2.98	0.01	0.0	0.25	2.88	2.66	28.5	0.45	7.72	0.32	0.78	2.13	4.99	0.33
190	4.52	0.0	0.0	0.85	4.58	4.10	14.3	0.24	9.56	3.33	0.975	1.71	4.14	0.56

Values above TEL range; Values above PEL range

Appendix Table 34. South Turning Basin 1 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.25	0.17	0.0	19.2	25.8	15.0	28.8	0.55	9.43	134	110	2.73	21.5	1.2
10	88.5	0.25	0.0	8.06	45.7	15.8	23.3	0.85	7.74	55.7	42.2	3.77	59.9	1.9
15	17.24	0.33	0.1	27.1	40.1	19.8	45.4	0.89	15.4	150.7	127	3.01	21.5	1.69
20	14.9	0.33	0.03	27.0	37.7	19.2	57.4	0.91	15.4	180	129	4.03	20.9	1.4
25	16.4	0.30	0.0	21.7	51.7	17.6	62.3	1.1	15.9	190	104	4.16	22.8	1.8
30	31.88	0.29	0.1	16.5	43.3	13.4	59.9	0.98	12.6	91.1	67.2	5.04	37.7	1.9
35	25.38	0.15	0.0	9.47	29.0	11.2	45.4	1.1	8.53	61.3	48.4	3.15	31.7	1.65
40	25.98	0.16	0.0	9.57	31.1	17.2	38.7	0.78	10.2	49.9	39.3	3.00	21.3	1.61
45	24.99	0.1	0.0	5.48	28.2	17.6	29.6	0.99	10.4	23.3	18.4	3.89	16.6	1.8
50	44.83	0.1	0.0	1.7	32.6	14.1	18.7	1.5	8.29	5.95	2.4	4.73	18.7	2.0
55	29.68	0.1	0.0	1.8	33.8	9.05	11.3	1.4	6.31	5.81	5.70	4.02	15.7	1.5
60	17.67	0.2	0.0	9.11	29.6	12.5	63.9	0.99	8.32	45.4	45.3	2.26	21.3	1.40
65	4.85	0.04	0.0	1.17	7.40	4.5	63.28	0.5	1.9	9.60	4.10	1.00	14.6	0.800
70	0.074	0.004	0.0	1.01	2.83	2.98	101.8	0.21	1.30	0.627	0.69	0.18	3.01	0.377
75	0.45	0.01	0.0	1.70	7.71	4.73	89.53	0.51	2.22	2.06	1.14	0.082	4.78	0.41

Values above TEL range; Values above PEL range

Appendix Table 35. South Turning Basin 2 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	8.67	0.26	0.12	22.6	30.5	17.2	38.8	0.67	12.7	132.5	115.0	2.80	15.5	1.33
10	9.75	0.34	0.19	27.4	37.5	20.2	49.3	0.76	15.9	155.8	135.3	3.71	15.1	1.61
15	9.49	0.35	0.16	28.3	39.4	20.3	44.7	0.78	16.4	156.6	136.5	2.95	13.9	1.67
20	14.5	0.08	0	5.07	16.7	5.86	17.7	0.52	5.11	22.3	35.0	8.14	15.6	0.30
25	8.97	0.04	0.0	0.64	6.85	5.82	4.07	0.46	2.5	11.6	1.3	4.52	9.11	0.46
30	3.05	0.051	0.0	5.09	6.81	3.45	8.55	0.16	2.59	27.7	22.8	1.03	4.73	0.25
35	9.84	0.04	0.0	0.48	8.4	4.6	3.4	0.6	2.0	5.00	1.20	8.60	12.6	0.50
40	8.57	0.0	0.0	0.69	5.06	3.0	8.33	0.62	1.8	8.32	2.6	7.19	14.5	0.42
45	14.6	0.05	0.0	0.83	7.49	2.6	4.1	0.71	1.3	23.7	1.7	10.3	14.5	0.63
50	14.8	0.1	0.0	0.26	6.76	2.80	5.31	0.66	1.5	4.47	0.36	11.1	13.3	0.41

Values above TEL range; Values above PEL range

Appendix Table 36. West Lake 1 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.0	0.04	0.01	5.77	3.44	5.35	28.4	0.12	1.49	49.8	30.4	0.580	8.12	0.39
10	0.05	0.065	0.0	7.52	4.14	5.47	28.4	0.14	1.72	47.2	25.3	0.47	9.04	0.37
15	0.581	0.089	0.044	8.47	4.98	5.82	27.8	0.16	1.84	38.6	17.9	0.687	8.38	0.32
20	0.833	0.13	0.088	11.0	9.20	8.75	35.9	0.35	2.87	19.2	10.1	1.21	6.22	0.425
25	0.22	0.088	0.0	6.53	4.30	6.39	24.0	0.21	1.60	11.5	5.55	0.502	5.28	0.25
30	0.24	0.050	0.0	3.28	4.76	6.01	18.1	0.28	1.52	4.07	1.95	0.586	4.63	0.25
35	0.34	0.087	0.056	6.40	5.37	7.33	26.0	0.26	1.82	19.4	10.3	0.837	4.21	0.29
40	0.23	0.072	0.0	4.70	5.17	7.46	43.5	0.34	1.78	5.82	3.05	0.454	2.96	0.26
45	0.58	0.28	0.20	16.4	8.30	8.37	55.9	0.37	3.07	30.5	15.6	0.904	10.4	0.45
50	0.789	0.11	0.15	11.9	7.43	6.66	72.60	0.35	2.76	23.3	11.7	1.18	12.5	0.52
55	0.51	0.10	0.21	10.0	6.47	5.18	63.17	0.30	2.28	20.4	9.26	0.49	10.8	0.57
60	0.856	0.045	0.003	7.10	5.32	4.13	70.62	0.29	1.55	12.8	4.10	0.827	10.3	0.567
65	0.34	0.02	0.0	4.87	4.04	3.30	55.4	0.21	1.35	7.80	3.15	0.38	11.7	0.49
70	0.583	0.04	0.0	5.00	4.86	3.39	72.34	0.25	1.31	10.9	2.96	0.28	14.0	0.713
75	1.39	0.04	0.0	3.36	4.09	2.96	70.07	0.28	1.23	6.60	1.63	0.585	12.1	0.593
80	0.27	0.01	0.0	0.642	1.21	0.973	80.13	0.18	0.438	1.07	0.430	0.31	4.85	0.18
85	0.0	0.004	0.0	1.07	1.34	2.80	78.98	0.22	0.649	0.916	0.29	0.19	2.60	0.12
90	0.0	0.01	0.0	1.64	2.04	3.39	71.0	0.25	0.72	4.94	1.53	0.30	3.18	0.18

Values above TEL range; Values above PEL range

Appendix Table 37. West Lake 2 Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

cm	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
5	0.31	0.10	0.0	11.4	4.94	6.80	34.6	0.17	1.98	37.7	21.1	0.502	6.42	0.27
10	0.074	0.070	0.0	7.24	4.08	6.35	26.8	0.18	1.63	28.3	14.0	0.61	5.23	0.29
15	0.0	0.032	0.0	2.04	2.36	5.17	15.2	0.17	1.08	8.48	1.03	0.34	1.68	0.17
20	0.20	0.045	0.0	4.23	4.36	6.24	17.8	0.27	1.65	2.44	6.70	0.31	3.54	0.26
25	0.16	0.074	0.01	4.54	5.45	7.29	22.6	0.29	1.85	7.15	4.02	0.676	2.99	0.25
30	0.21	0.072	0.0	5.01	5.14	7.53	54.8	0.39	2.01	8.96	4.81	0.064	3.25	0.25
35	0.090	0.18	0.060	7.83	5.92	4.57	46.3	0.21	2.24	16.6	8.95	0.624	11.0	0.56
40	0.46	0.21	0.26	13.1	6.50	6.67	70.1	0.33	2.64	21.1	11.7	0.48	12.3	0.60
45	0.55	0.091	0.12	10.2	5.58	5.64	75.3	0.32	2.21	16.0	9.12	0.53	11.2	0.647
50	0.65	0.12	0.11	11.6	7.85	7.21	78.7	0.41	2.88	21.2	11.4	0.49	12.6	0.55
55	0.41	0.1	0.04	8.96	5.12	4.56	66.1	0.30	1.92	16.8	7.89	0.50	10.6	0.53
60	0.726	0.04	0.0	6.51	5.78	4.29	77.2	0.31	1.61	8.65	2.99	0.45	10.5	0.51
65	0.956	0.053	0.0	5.68	5.36	4.10	66.6	0.31	1.59	9.12	3.52	0.39	13.8	0.43
70	0.975	0.055	0.0	4.54	6.15	4.13	66.5	0.29	1.65	10.9	2.43	0.58	11.0	0.56
75	3.6	0.016	0.0	0.59	59.6	11.2	9.38	0.52	16.8	27.7	1.2	7.70	12.9	0.88
80	2.04	0.012	0.0	0.965	2.24	1.94	57.13	0.28	0.975	2.45	0.513	0.675	21.7	0.704
85	0.813	0.033	0.0	2.19	2.78	2.53	70.81	0.22	1.17	7.41	0.927	0.957	8.75	0.46
90	0.04	0.00	0.0	0.14	0.43	0.34	93.77	0.19	0.597	0.41	0.26	0.601	4.62	0.21

Values above TEL range; Values above PEL range

Appendix Table 38. North Reef Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
NR1	0	0.01	0	0.9	5.02	4.7	10.1	0.04	0.41	2.76	0.67	0.99	6.89	0.11
NR 2	0	0.03	0	1.4	6.8	6.81	13.9	0.1	0.72	4.52	1.02	1.84	6.37	0.04
NR 3	0.01	0.04	0	1.5	9.12	7.55	15.6	0.04	0.6	3.24	0.65	1.6	8.55	0.08

Values above TEL range; Values above PEL range

Appendix Table 39. South Reef Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for every 5 cm in depth.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
SR 1	0	0.04	0	1.3	3.8	5.32	24.1	0.03	0.62	91.1	28.6	1.85	2.41	0.07
SR 2	0	0.03	0	1.5	4.19	6.35	13.6	0.03	0.75	3.85	0.59	2.07	3.82	0.12
SR 3	0	0.04	0	1.8	3.91	6.44	14.6	0.05	0.86	6.97	0.51	1.34	3.32	0.08

Values above TEL range; Values above PEL range

Appendix Table 40: Elemental Concentrations in Marine Port Sediment

Trace Element	Conc. in Marine Sediment	Location	References
As	4 – 29 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	6.7 – 19.9 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	8.0 – 21.0 µg/g	Naples, Italy*	Adamo, et al. 2005
	0.8 – 223 µg/g	Fort Lauderdale, Florida, USA*	This Study
Cd	0.1 – 0.4 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	0.09 – 0.47	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	0.2 – 2.5 µg/g	Naples, Italy*	Adamo, et al. 2005
	0.0 – 0.92 µg/g	Fort Lauderdale, Florida, USA*	This Study
Cr	1 – 31 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	8.4 – 90.4 µg/g	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	0.34 – 56.8 µg/g	Fort Lauderdale, Florida, USA*	This Study
	10.3 – 161.8 µg/g	Naples, Italy*	Adamo, et al. 2005
Co	1 – 12 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	1.9 – 7.2 µg/g	Naples, Italy*	Adamo, et al. 2005
	0.02 – 7.40 µg/g	Fort Lauderdale, Florida, USA*	This Study
Cu	2 – 1195 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	17.6 – 37.8 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	2.9 – 28.7 µg/g	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	0.29 – 210 µg/g	Fort Lauderdale, Florida, USA*	This Study
	40 – 415 µg/g	Naples, Italy*	Adamo, et al. 2005
Hg	0.5 – 2.73 µg/g	Persian Gulf, Iran*	Abdollahi, et al. 2013
	0.005 – 0.31 µg/g	District of Klang, Malaysia	Tavakoly Sany, et al. 2012
	0.018 – 0.536 µg/g	South Korea*	Choi, et al. 2011
	0.0 – 0.74 µg/g	Fort Lauderdale, Florida, USA*	This Study
Pb	2 – 165 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	10.7 – 30.2 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	6.7 – 34.0 µg/g	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	0.06 – 35.9 µg/g	Fort Lauderdale, Florida, USA*	This Study
	37 – 314 µg/g	Naples, Italy*	Adamo, et al. 2005
Mn	6 – 201 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	95 – 535 µg/g	Naples, Italy*	Adamo, et al. 2005
	316.6 – 325.6 µg/g	Persian Gulf, Iran*	Abdollahi, et al. 2013
	1.6 – 203.6 µg/g	Fort Lauderdale, Florida, USA*	This Study
Mo	40 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	0.7 – 1.8 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	0.5 – 5.3 µg/g	Naples, Italy*	Adamo, et al. 2005
	0.0 – 384.5 µg/g	Fort Lauderdale, Florida, USA*	This Study
Ni	3 – 20 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	61.3 – 109.4 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	3.2 – 47.1 µg/g	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	0.42 – 19.5 µg/g	Fort Lauderdale, Florida, USA*	This Study
Se	0.4 – 8.8 µg/g	New South Wales, Australia	Peters, et al. 1999
	0.2 – 1.7 µg/g	Solomon River, Kansas, USA	May, et al, 2007
	0.2 – 0.3 µg/g	Kuskokwim River, Alaska, USA	Belkin, et al. 1993
	0.05 – 6.8 µg/g	Fort Lauderdale, Florida, USA*	This Study
Sn	3 – 37 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	0.0 – 140.1 µg/g	Fort Lauderdale, Florida, USA*	
V	2.5 – 13.5 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018

	18 – 94 µg/g	Naples, Italy*	Adamo, et al. 2005
	30.6 – 32.5 µg/g	Persian Gulf, Iran*	Abdollahi, et al. 2013
	0.2 – 176.2 µg/g	Fort Lauderdale, Florida, USA*	This Study
Zn	7 – 2345 µg/g	New South Wales, Australia*	Jahan and Strezov, 2018
	54.0 – 99.0 µg/g	Koper, Slovenia*	Rogan Šmuc, et al. 2018
	12.8 – 88.6 µg/g	Laizhou Bay and Zhangzi Island, China	Zhuang & Gao, 2014
	41 – 1196 µg/g	Naples, Italy*	Adamo, et al. 2005
	0.63 – 387 µg/g	Fort Lauderdale, Florida, USA*	This Study

* Indicates Port sediment

Appendix Table 41. Dania Cutoff Canal Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As
Mo													
Cd	0.31895												
Hg	0.05971	0.33996											
Pb	0.28391	0.70701	0.22535										
V	0.51219	0.91435	0.29105	0.68849									
Cr	0.37652	0.91585	0.26987	0.77801	0.87159								
Mn	0.13746	0.19602	0.053016	0.17501	0.17753	0.17128							
Co	0.47016	0.71818	0.17737	0.755	0.72925	0.69291	0.57301						
Ni	0.38625	0.95439	0.27229	0.77227	0.9013	0.98932	0.21886	0.73559					
Zn	0.14609	0.27868	-0.02276	0.21599	0.34674	0.18143	0.31597	0.43038	0.21587				
Cu	0.061395	0.28193	0.077963	0.51971	0.25956	0.32735	0.10933	0.23218	0.31515	0.28876			
Sn	0.19494	0.69784	-0.02284	0.48156	0.66174	0.75464	0.26851	0.54298	0.77224	0.17675	0.20446		
As	0.87641	0.6184	0.11814	0.45831	0.72686	0.58812	0.33985	0.70448	0.63128	0.33525	0.16189	0.42931	
Se	0.59534	0.88579	0.45067	0.70314	0.8882	0.92567	0.28124	0.74302	0.93201	0.22567	0.28915	0.63796	0.77447

Appendix Table 42. Park Education Center Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As
Mo													
Cd	0.4334												
Hg	0.040418	0.49852											
Pb	0.060458	0.70758	0.4659										
V	0.64355	0.41727	0.15549	0.30976									
Cr	0.28435	0.54376	0.16061	0.58175	0.53808								
Mn	0.42017	0.45919	0.28829	0.58612	0.64529	0.62441							
Co	0.39742	0.27819	0.0096484	0.21038	0.55015	0.59878	0.22887						
Ni	0.30435	0.66753	0.34107	0.67701	0.57453	0.77351	0.48006	0.73138					
Zn	-0.01342	0.33475	0.15	0.54746	0.11869	0.31123	0.28762	0.081873	0.34303				
Cu	0.045701	0.58131	0.32072	0.8888	0.3066	0.59934	0.61091	0.19688	0.6468	0.58359			
Sn	0.086317	0.072237	0.018941	0.13047	0.14402	0.21617	0.28128	-0.01227	0.097456	0.28008	0.23073		
As	0.92858	0.57113	0.194	0.2929	0.75094	0.49473	0.58405	0.55508	0.55765	0.097515	0.26043	0.11738	
Se	0.72305	0.66337	0.22719	0.37468	0.76243	0.6568	0.5601	0.65676	0.74041	0.21794	0.32516	0.098866	0.85846

Appendix Table 43. Park Headquarters Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6. Mercury (Hg) was excluded due to n/d values.

	Mo	Cd	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
Mo													
Cd	0.4782												
Pb	0.54429	0.60933											
V	0.7734	0.59824	0.53638										
Cr	0.73775	0.62569	0.60431	0.915									
Mn	0.13977	0.14684	0.084664	0.2948	0.30095								
Co	0.030285	-0.01038	-0.1179	0.11848	0.14616	0.4873							
Ni	0.49133	0.59286	0.41303	0.63456	0.69232	0.56635	0.54058						
Zn	0.033764	-0.04751	0.044717	0.23003	0.18136	0.08726	0.046178	0.064956					
Cu	0.67321	0.47885	0.89541	0.57257	0.59371	0.11864	-0.05809	0.38882	0.059088				
Sn	0.36813	0.1107	0.17355	0.62019	0.55965	0.51066	0.41252	0.59841	0.51929	0.29424			
As	0.8717	0.41885	0.46952	0.75788	0.78685	0.23142	0.13316	0.47554	0.040993	0.53154	0.36523		
Se	0.82425	0.62964	0.55937	0.88894	0.91808	0.3706	0.24776	0.73015	0.186	0.63149	0.67579	0.80446	

Appendix Table 44. South Turning Basin Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
Mo														
Cd	0.60114													
Hg	0.13115	0.69582												
Pb	0.39235	0.95965	0.75087											
V	0.76505	0.93598	0.51784	0.84848										
Cr	0.6745	0.93939	0.5955	0.89383	0.96371									
Mn	0.38138	0.6627	0.38086	0.6415	0.68427	0.70663								
Co	0.76533	0.75353	0.34029	0.63565	0.89973	0.8648	0.65246							
Ni	0.58843	0.96793	0.65559	0.94421	0.96001	0.98121	0.70188	0.82728						
Zn	0.39015	0.94486	0.67264	0.98346	0.84412	0.87163	0.6218	0.6299	0.9273					
Cu	0.37256	0.94656	0.74711	0.99636	0.82735	0.87639	0.61201	0.60635	0.92533	0.98399				
Sn	0.5606	0.49266	0.223	0.38723	0.566	0.5524	0.31637	0.64937	0.51489	0.414	0.36753			
As	0.9105	0.77673	0.28188	0.62741	0.87792	0.81239	0.5948	0.83658	0.76044	0.6346	0.61252	0.65046		
Se	0.79501	0.87733	0.4688	0.77556	0.97547	0.9592	0.70048	0.94612	0.92873	0.7601	0.7509	0.61645	0.88955	

Appendix Table 45. West Lake Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by $R > 0.6$.

	Mo	Cd	Hg	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
Mo														
Cd	0.27489													
Hg	0.19117	0.78528												
Pb	0.31752	0.92393	0.74666											
V	0.83283	0.30132	0.20035	0.30462										
Cr	0.55628	0.77275	0.47966	0.81886	0.64753									
Mn	0.43182	0.54802	0.43223	0.66161	0.23841	0.58912								
Co	0.68214	0.69427	0.47896	0.75721	0.6277	0.90812	0.81546							
Ni	0.82838	0.28539	0.26998	0.39162	0.99349	0.71365	0.30306	0.68643						
Zn	0.37024	0.67814	0.45594	0.78665	0.45783	0.76202	0.43901	0.58484	0.52748					
Cu	0.14234	0.67424	0.46182	0.78238	0.22152	0.67146	0.38596	0.46896	0.30319	0.9522				
Sn	0.84169	0.23088	0.13945	0.23008	0.98114	0.58757	0.21453	0.5751	0.97149	0.42884	0.18646			
As	0.73024	0.61164	0.46273	0.7128	0.4864	0.68005	0.80406	0.82475	0.54048	0.62161	0.51408	0.45871		
Se	0.76582	0.64293	0.48141	0.73435	0.6197	0.78282	0.79508	0.896	0.67058	0.6477	0.51249	0.58367	0.96084	

Appendix Table 46. North Reef Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6. Molybdenum (Mo) and Mercury (Hg) excluded due to n/d values.

	Cd	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
Cd												
Pb	0.98432											
V	0.96482	0.90333										
Cr	0.99675	0.99533	0.94053									
Mn	0.99964	0.9887	0.95742	0.99856								
Co	0.18898	0.35921	-0.07582	0.26743	0.21527							
Ni	0.74688	0.85245	0.5458	0.79799	0.76446	0.79412						
Zn	0.44133	0.59268	0.1899	0.51214	0.46526	0.96458	0.92632					
Cu	0.14157	0.31395	-0.12365	0.22081	0.1681	0.99884	0.764	0.95079				
Sn	0.81916	0.900748	0.63956	0.86268	0.83426	0.71804	0.99321	0.87621	0.68376			
As	0.58647	0.43442	0.77877	0.51935	0.56451	-0.6846	-0.1006	-0.468	-0.7188	0.015833		
Se	-0.5903	-0.72341	-0.35733	-0.61534	-0.6118	-0.9042	-0.9776	-0.9848	-0.8826	-0.9465	0.30761	

Appendix Table 47. South Reef Pearson Correlation Coefficients (R) displaying relationship between elements within sediment cores, Strong correlations represented by R > 0.6. Molybdenum (Mo) and Mercury (Hg) excluded due to n/d values.

	Cd	Pb	V	Cr	Mn	Co	Ni	Zn	Cu	Sn	As	Se
Cd												
Pb	0.75593											
V	0.029344	-0.63219										
Cr	0.69338	0.052414	0.74061									
Mn	-0.46026	0.23327	-0.99009	-0.9589								
Co	1	0.75593	0.029344	0.69338	-0.4603							
Ni	0.64046	0.98691	-0.74886	-0.1093	0.38703	0.64046						
Zn	-0.46707	0.22578	-0.89754	-0.961	0.99997	-0.46707	0.37992					
Cu	-0.50037	0.18856	-0.88012	-0.9708	0.99895	-0.50037	0.34447	0.99928				
Sn	-0.94153	-0.9323	0.20916	-0.4100	0.13422	-0.94153	-0.8618	0.14184	0.17939			
As	0.047617	-0.61792	0.99983	0.75278	-0.9087	0.047617	-0.7366	-0.9055	-0.8887	0.29172		
Se	-0.90419	-0.40389	-0.45347	-0.9347	0.79536	-0.9042	-0.2511	0.79999	0.82224	0.70741	-0.469	